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HENRY S. GRAVES, Forester
FOREST PRODUCTS LABORATORY, Madison, Wisconsin
In Cooperation with the University of Wisconsin

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THE RELATION OF THE SHRINKAGE AND STRENGTH PROPERTIES OF WOOD TO ITS SPECIFIC GRAVITY.

By J. A. NEWLIN, *in charge, Section of Timber Mechanics,* and T. R. C. WILSON, *Engineer in Forest Products.*

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PURPOSE.

It has long been recognized that there are direct relations between the specific gravity, or density, of a wood and its strength properties.[1] By the analysis of over 200,000 tests, the Forest Products Laboratory, conducted in cooperation with the University of Wisconsin, Madison, Wis., has now definitely established these relations. It is the purpose of this bulletin to state these relations and to put the expression of them in such form as to render them easily useful (1) for estimating the properties of any particular timber; (2) for selecting timber for any given purpose; (3) for comparing the various species; and (4) for determining in what way the species are exceptional and to what uses they are best adapted.

It has usually been assumed that the strength of wood varies directly with the first power of its density; i.e., that the respective strengths of two sticks would differ in the same proportion as the densities. It was recognized that fiber stress at elastic limit in compression perpendicular to the grain, or bearing strength on side surface, and work values in static bending or toughness, deviate very erratically from this relation; but the relation was supposed to hold especially true in the case of such properties as modulus of rupture, or maximum bending strength, and strength in compression parallel

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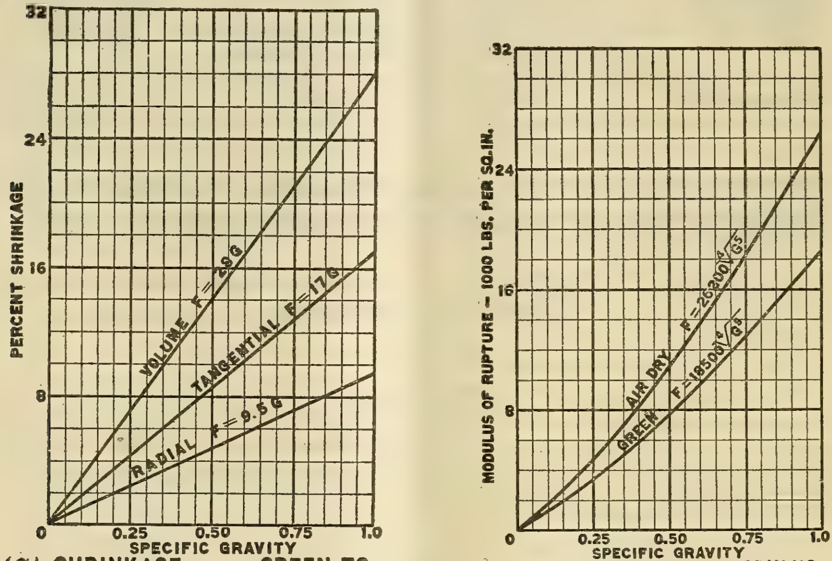
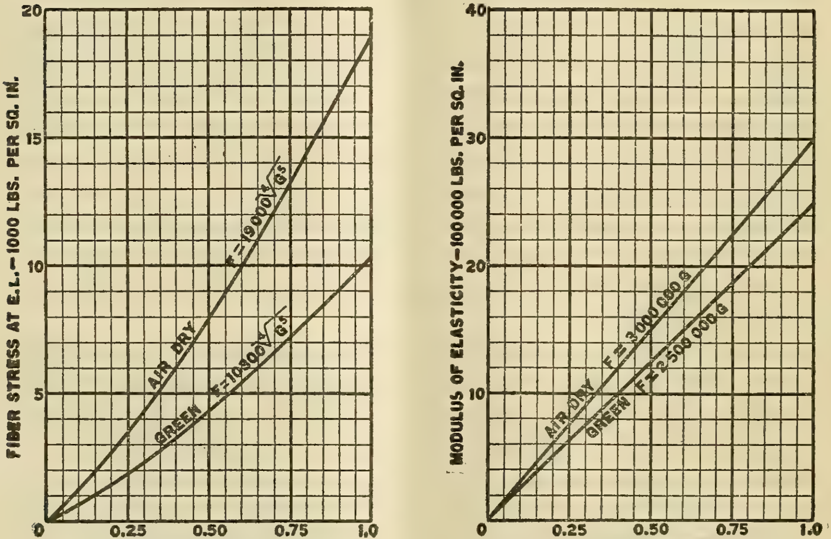
[1] Accurate determinations made at the Forest Products Laboratory on seven species of wood, including both hardwood and coniferous species, showed a range of only about 4½ per cent in the density of the wood substance, or material of which the cell walls are composed. Since the density of wood substance is so nearly constant, it may be said that the density or specific gravity of a given piece of wood is a measure of the amount of wood substance contained in it.



(a) SHRINKAGE — GREEN TO OVEN DRY CONDITION

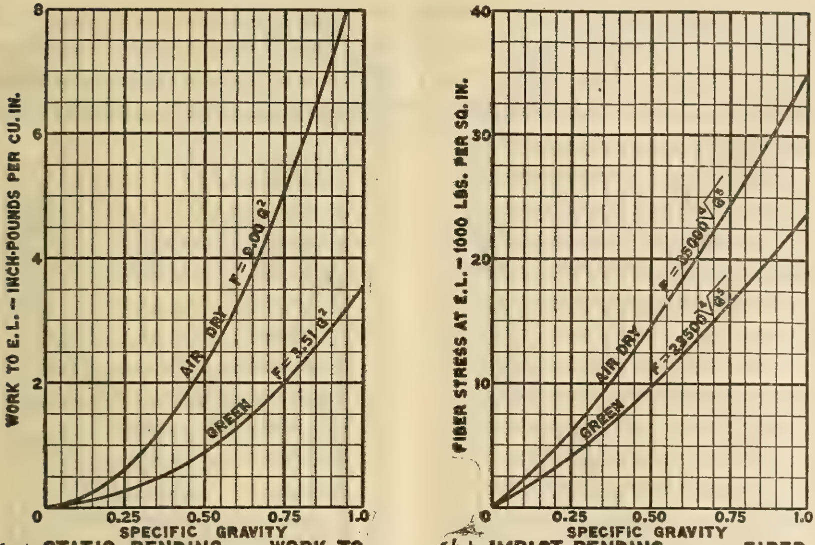
(B) STATIC BENDING—MODULUS OF RUPTURE



(c) STATIC BENDING — FIBER STRESS AT ELASTIC LIMIT

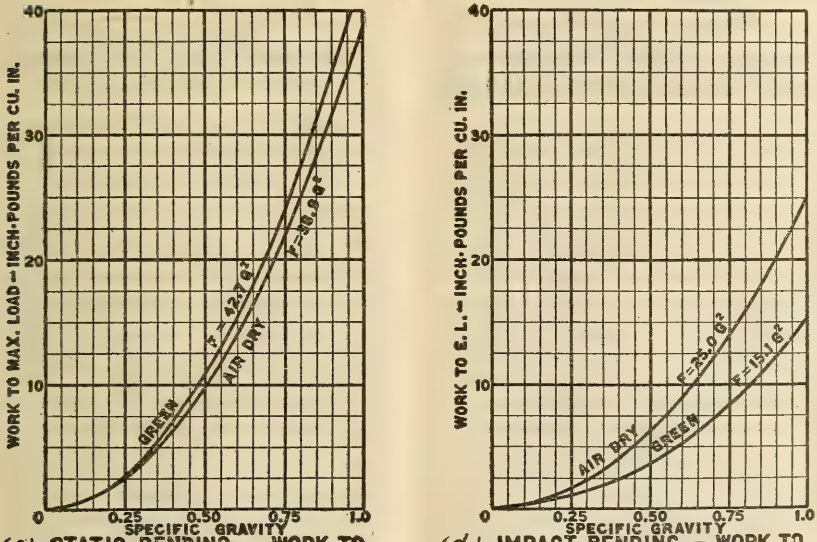
(d) STATIC BENDING — MODULUS OF ELASTICITY

FIG. 1.



(a) STATIC BENDING — WORK TO ELASTIC LIMIT

(b) IMPACT BENDING — FIBER STRESS AT ELASTIC LIMIT

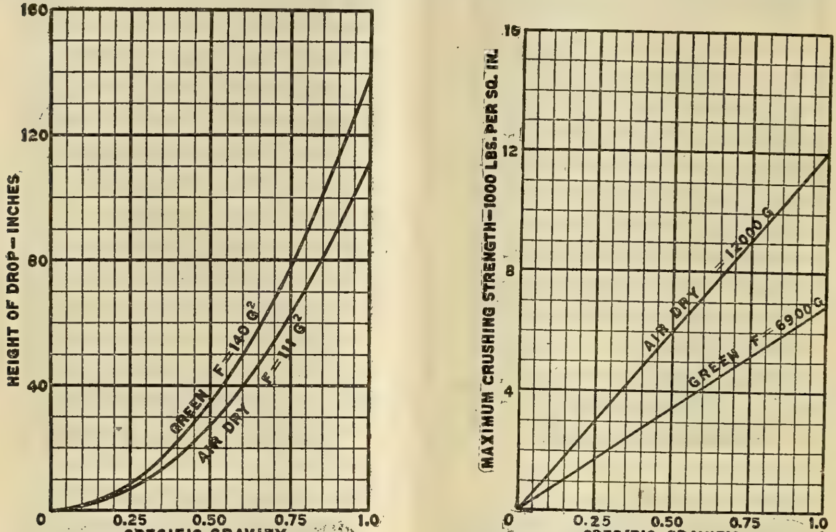


(c) STATIC BENDING — WORK TO MAXIMUM LOAD

(d) IMPACT BENDING — WORK TO ELASTIC LIMIT

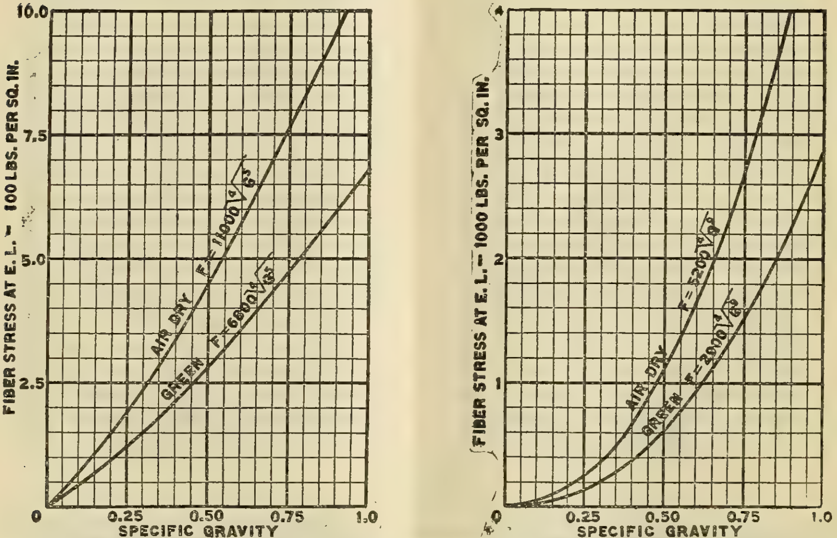
Fig. 2.

to the grain, or strength as a column. It has also been supposed that the relation applied between pieces of the same species, between pieces of different species, and between average results of strength tests on different species. A study of the data at present available, which are derived from a much larger number of tests and which cover a greater range in specific gravity and strength values than was true of the data available heretofore, made it evident that these assumptions were inaccurate and that there was a better and more correct method expressing the actual relations between specific gravity and strength.



(a) IMPACT BENDING — HEIGHT OF DROP CAUSING COMPLETE FAILURE

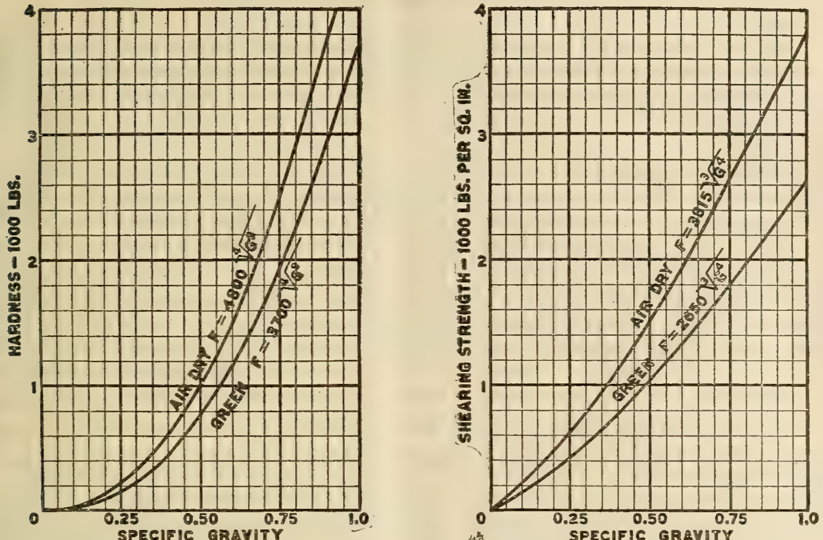
(B) COMPRESSION ∥ TO GRAIN MAXIMUM CRUSHING STRENGTH



(c) COMPRESSION ∥ TO GRAIN FIBER STRESS AT ELASTIC LIMIT

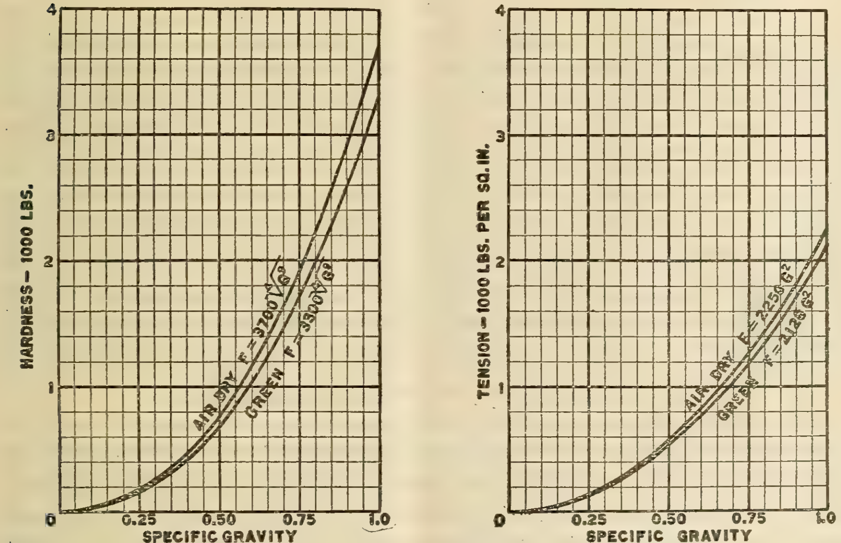
(d) COMPRESSION ⊥ TO GRAIN FIBER STRESS AT ELASTIC LIMIT

Fig. 3.



(a) **Hardness – End Surface**

(b) **Shearing Strength || to Grain**



(c) **Hardness – Side Surface**

(d) **Tension ⊥ to Grain**

Fig. 4.

In order that the relation between specific gravity and each of the various mechanical properties of wood may be easily put to practical use, the relation, both for green and for air-dry material, is given in the form of an equation (Table 1) and, in addition, in the form of a curve (figs. 1 to 4).

SPECIES-LOCALITY AVERAGES.

The specific-gravity relations given in this bulletin are derived from a study of what may be called ''species-locality'' averages; that is, each average represents tests of material of one species from one locality.

There are two principal reasons for using ''species-locality'' averages in preference to the results of individual tests. First, the number of individual tests is quite large, amounting in some instances to as many as 900 from a single ''species-locality'', so that an immense amount of work is saved by the use of the ''species-locality'' averages; second, if individual tests were used, the ''species-localities'' having larger trees or a larger number of trees would include a larger number of tests and would have undue weight in determining the relations.

The method of analysis used is applicable also to individual tests from a single species to determine the specific gravity relations within that species. It has been applied to a few of the properties of some of the more important species which are used for structural timbers where there was a rather large number of test pieces and a considerable range in specific gravity.

DETERMINATION OF SPECIFIC GRAVITY.

Specific gravity of wood, as used herein, is based on the volume of the specimens when tested (green or air-dry) and their weight when in an oven-dry condition; that is, it is the ratio of the weight of the specimen of wood, *oven-dry,* to the weight of a volume of water equal to the *volume of the specimen at the time of test.* Because of the shrinkage which takes place in wood when it is dried, this figure is not the true specific gravity of a piece of oven-dry wood. The method, however, is easily applied to each specimen tested, and is the standard method of the Forest Service for the determination of a specific-gravity figure for use in studying the properties of wood.

MOISTURE CONTENT OF TEST SPECIMENS.

Both green and air-dry specimens were used in the tests, and the relations between specific gravity and strength were determined separately for green and air-dry wood. Variations in the moisture content of wood have no effect on its mechanical properties so long as the wood is thoroughly green; they have considerable influence on these properties, however, as soon as the wood becomes air-dry, or partially air-dry. Accurate comparisons can not be made between the properties of two lots of air-dry specimens unless they were tested at the same moisture content or adjustments made in the strength figures for difference in moisture content.

The moisture content of the air-dry material at the time of test varied from 8 to 18 per cent. Modulus of rupture and maximum strength in compression parallel to the grain were adjusted to a moisture content of 12 per cent before determinations of the relation of these properties to the specific gravity was made. This adjustment was possible because the laws governing the variation of these properties with varying moisture content are fairly well established. However, in the case of the other strength functions their variation with varying moisture content has not been studied in detail and no such adjustment is possible with any very great degree of accuracy. Consequently, the actual moisture content values as obtained from tests have been used in the determination of the relation of these properties to specific gravity.

THE EQUATIONS.

Table 1 and figures 1 to 4 give equations which represent the average relations between specific gravity and each of the mechanical properties. All the ''species-locality'' averages available on any particular property were considered in deriving the equations for that property. The number of ''species-locality'' averages from which an equation is derived varies from 84 to 178. This variation is due to the fact that several of the tests were not used in some of the earlier testing work and to the fact that tests have not yet been completed on air-dry material for all of the ''species-localities'' listed.

Table 1 gives first the equations for shrinkage and for each of the strength properties of green and air-dry wood in terms of the specific gravity. These equations, as explained in the appendix, are reduced to a simple form; and the powers of gravity used are such that the equations may be solved by arithmetical operations and without the use of higher mathematics. However, to simplify even further the use of the equations, figures 1 to 4 have been prepared for their solution. Each of the curves shown in these diagrams represents the equation connecting specific gravity and one of the properties of wood. The curves representing the equations for radial, tangential, and volumetric shrinkage appear in figure 1(a). In each of the other figures, 1(b) to 4(d), appear two curves for some one mechanical property. One of these curves is for green and the other for air-dry material. If the specific gravity is known, the equation value for any one or all of the properties of the wood in question may be readily determined from the curves without computation.

The second portion of Table 1 gives what may be termed a measure of the accuracy of the respective equations. It is not to be expected that all the "species-locality" averages will satisfy the equation exactly or even very closely. Some of the properties are more erratic than others, so that one "species-locality" may far exceed the equation values and another "species-locality" fall far below them.

In figure 5 are plotted the curves of the equation for modulus of rupture in static bending in green material, $M=18500\sqrt[4]{g^5}$, and of the equation for the same property in air-dry material, $M=26200\sqrt[4]{g^5}$. In order to give a graphical idea as to the reliability of these equations, the specific gravity and the modulus of rupture of each "species-locality" have been plotted as a point. The reference number placed near each plotted point is assigned to the "species-locality" in the order of its respective specfic gravity as determined from compression parallel to grain specimens of green wood. In figures 6, 7, and 8 the data are given for the curves on shrinkage in volume from green to oven-dry condition, maximum crushing strength in compression parallel to grain, and fiber strength at elastic limit in compression perpendicular to grain.

Under each property is listed in this second portion of Table 1, for both green and air-dry conditions, those percentages of the equation value above which were one-tenth of the "species-localities." Similarly, there are listed those percentages above which were one-fourth of the "species-localities," those below which were one-fourth, and those below which were one-tenth. For instance, in static bending (green), one-tenth of the "species-localities" tested had a modulus of rupture of more than 114 per cent of what the specific gravity equation indicated they should have had; one-fourth of them had a modulus of rupture greater than 108 per cent of the equation value; one-fourth of them less than 91 per cent of the equation value; and the lowest one-tenth had a modulus of rupture less than 84 per cent of what the equation indicated they should have had. It follows from these figures that one-half of the "species-localities" had a modulus of rupture of between 91 per cent and 108 per cent of the value given by the equation, and that the other one-half were evenly divided between those that were more than 108 per cent and those that were less than 91 per cent.

The third portion of Table 1 gives the actual value of each property for each "species-locality" as determined by the tests, expressed as a percentage of the value computed from the specific gravity by the use of the equation at the head of the column. For instance, it is found from the table that air-dry Biltmore ash has a modulus of rupture 98 per cent as great as that of the average wood of its specific gravity, the modulus of rupture of the average wood of this specific gravity being the figure given by the equation. These percentages are given for both green and air-dry wood.

LIST OF SPECIES AND REFERENCE NUMBERS FOR FIGURES 5 TO 9.

HARDWOODS.

Species.	Locality.	Reference No.
Alder, red	Washington	30
Ash:		
Biltmore	Tennessee	91
Black	Michigan	60
Do	Wisconsin	70
Blue	Kentucky	99
Green	Louisiana	93
Do	Missouri	100
Pumpkin	do	79
White	Arkansas	106
Do	New York	128
Do	West Virginia	83
Aspen	Wisconsin	23
Largetooth	do	20
Basswood	Pennsylvania	12
Do	Wisconsin	5
Beech	Indiana	110
Do	Pennsylvania	98
Birch:		
Paper	Wisconsin	73
Sweet	Pennsylvania	129
Yellow	do	107
Do	Wisconsin	103
Buckeye, yellow	Tennessee	9
Buckthorn, cascara	Oregon	84a
Butternut	Tennessee	27
Do	Wisconsin	21
Chinquapin, western	Oregon	46b
Cherry:		
Black	Pennsylvania	72
Wild red	Tennessee	24
Chestnut	Maryland	46
Do	Tennessee	40
Cottonwood, black	Washington	6
Cucumber tree	Tennessee	59
Dogwood:		
Flowering	do	151
Western	Oregon	125a
Elder, pale	do	69a
Elm:		
Cork	Wisconsin, Marathon County.	126
Do	Wisconsin, Rusk County.	120
Slippery	Indiana	102
Do	Wisconsin	74
White	Pennsylvania	55
Do	Wisconsin	53
Greenheart		165
Gum:		
Black	Tennessee	68
Blue (Eucalyptus).	California	147
Cotton	Louisiana	76
Red	Missouri	54
Hackberry	Indiana	90
Do	Wisconsin	78
Haw, pear	do	146
Hickory:		
Big shellbark	Mississippi	135
Do	Ohio	154
Bitternut	do	139
Mockernut	Mississippi	144
Do	Pennsylvania	159
Do	West Virginia	5
Nutmeg	Mississippi	112
Pignut	do	148
Do	Ohio	157
Do	Pennsylvania	160
Do	West Virginia	161
Hickory—Continued.		
Shagbark	Mississippi	140
Do	Ohio	152
Do	Pennsylvania	143
Do	West Virginia	153
Water	Mississippi	141
Holly, American	Tennessee	87
Hornbeam	do	149
Laurel, mountain	do	145
Locust:		
Black	do	158
Honey	Indiana	162
Madrona	California	101
Do	Oregon	128a
Magnolia	Louisiana	66
Maple:		
Oregon	Washington	58
Red	Pennsylvania	69
Do	Wisconsin	92
Silver	do	56
Sugar	Indiana	104
Do	Pennsylvania	108
Do	Wisconsin	124
Oak:		
Bur	do	125
California black	California	80
Canyon live	do	163
Chestnut	Tennessee	121
Cow	Louisiana	133
Laurel	do	116
Post	Arkansas	130
Do	Louisiana	137
Red	Arkansas	119
Do	Indiana	118
Do	Louisiana	117
Do	Tennessee	97
Highland Spanish.	Louisiana	94
Lowland Spanish	do	142
Swamp white	Indiana	150
Tanbark	California	115
Water	Louisiana	111
White	Arkansas	132
Do	Indiana	138
Do	Louisiana, Richland Parish.	136
Do	Louisiana, Winn Parish.	131
Willow	Louisiana	109
Yellow	Arkansas	122
Do	Wisconsin	105
Osage orange	Indiana	164
Poplar, yellow (tulip tree).	Tennessee	35
Rhododendron, great	do	85
Sassafras	do	51
Serviceberry	do	156
Silverbell tree	do	49
Sourwood	do	89
Sumac, staghorn	Wisconsin	61
Sycamore	Indiana	63
Do	Tennessee	65
Umbrella, Fraser	do	45
Willow:		
Black	Wisconsin	11
Western black	Oregon	43a
Witch hazel	Tennessee	114

CONIFERS.

Species.	Locality.	Reference No.
Cedar:		
Incense	California	26
Western red	Montana	2
Do	Washington	10
White	Wisconsin	1
Cypress, bald	Louisiana	62
Douglas fir	California	45a
Do	Oregon	67a
Do	Washington, Chehalis County.	46a
Do	Washington, Lewis County.	75
Do	Washington and Oregon.	67
Do	Wyoming	48
Fir:		
Alpine	Colorado	4
Amabilis	Oregon	39
Do	Washington	18
Balsam	Wisconsin	14
Grand	Montana	36
Noble	Oregon	16
White	California	17
Hemlock:		
Black	Montana	47
Eastern	Tennessee	52
Do	Wisconsin	15
Western	Washington	50
Larch, western	Montana	84
Do	Washington	64
Pine:		
Cuban	Florida	127
Jack	Wisconsin	43
Jeffrey	California	33
Loblolly	Florida	88
Lodgepole	Colorado	31
Do	Montana, Gallatin County.	35a
Pine—Continued.		
Lodgepole	Montana, Granite County.	41a
Do	Montana, Jefferson County.	40a
Do	Wyoming	34
Longleaf	Florida	123
Do	Louisiana, Lake Charles.	113
Do	Louisiana, Tangipahoa Parish.	96
Do	Mississippi	95
Norway	Wisconsin	57
Pitch	Tennessee	71
Pond	Florida	86
Shortleaf	Arkansas	77
Sugar	California	22
Table Mountain	Tennessee	82
Western white	Montana	42
Western yellow	Arizona	19
Western	California	37
Do	Colorado	41
Do	Montana	32
White	Wisconsin	25
Redwood	California, Albion	28
Do	California, Korbel	13
Spruce:		
Engelmann	Colorado, Grand County.	8
Do	Colorado, San Miguel County.	3
Red	New Hampshire	44
Do	Tennessee	29
White	New Hampshire	7
Do	Wisconsin	38
Tamarack	do	81
Yew, western	Washington	134

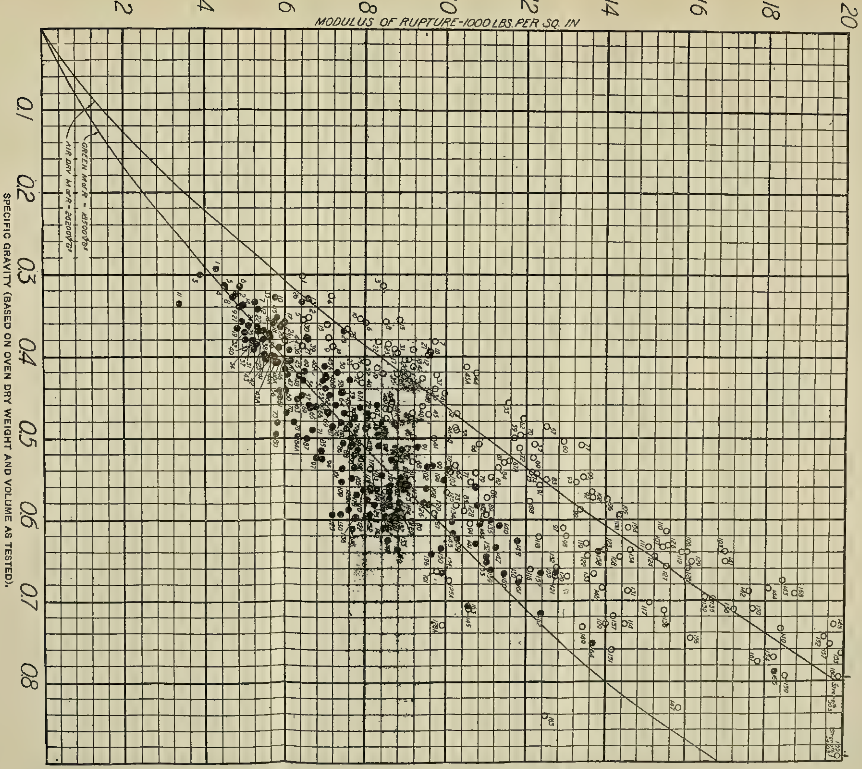
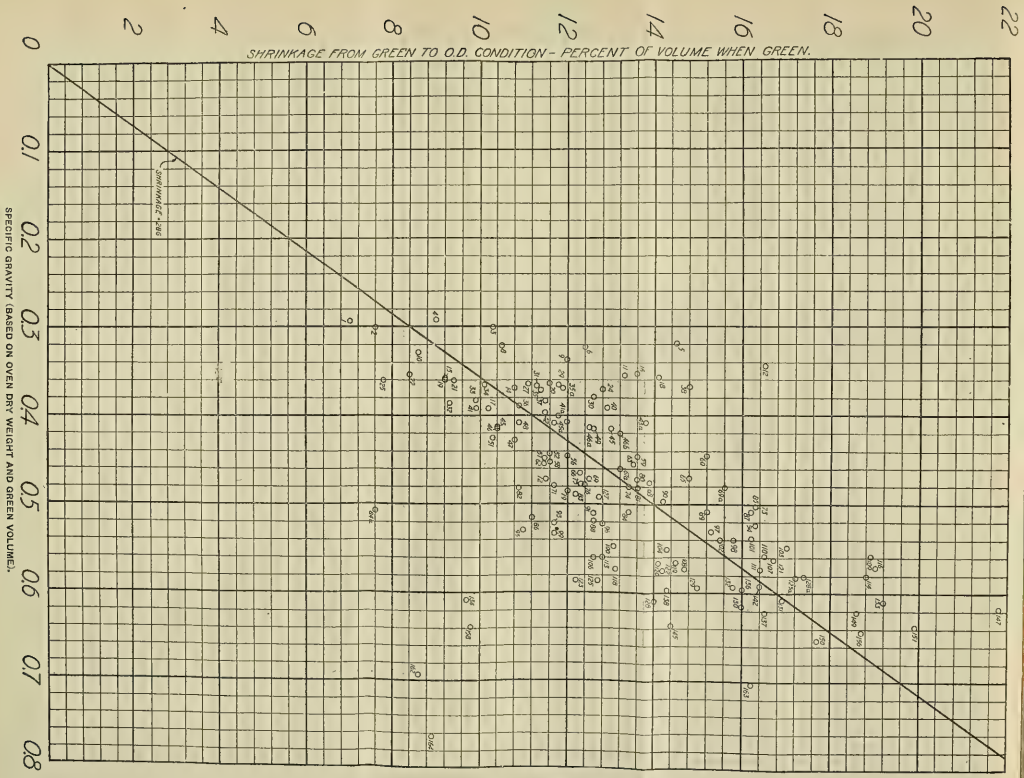


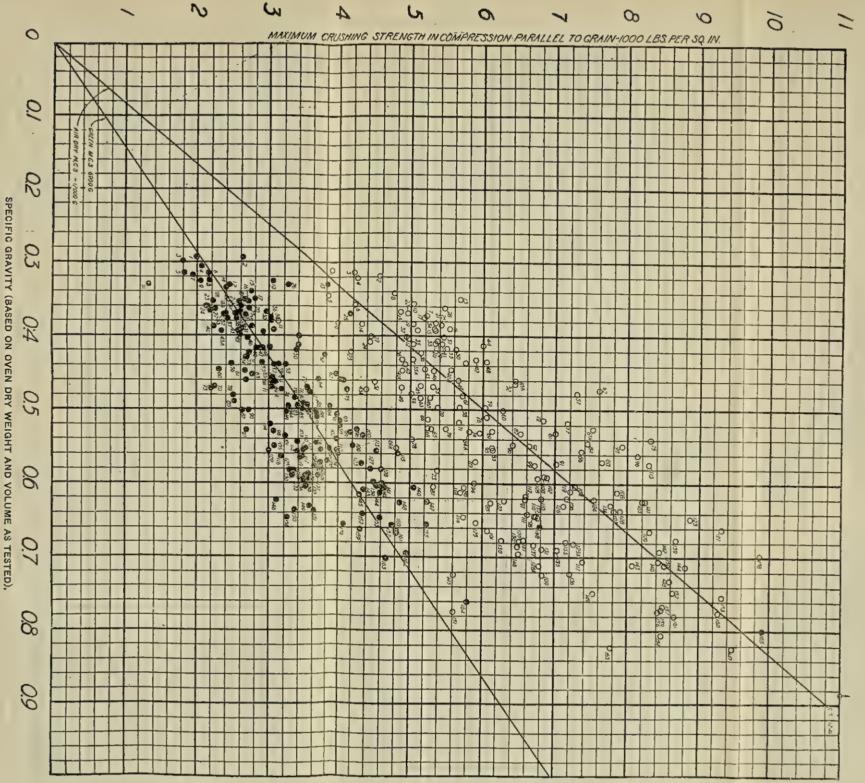
FIG. 5.—Relation of modulus of rupture in static bending to specific gravity.

65977°—19. (To precede page 9.) No. 2.



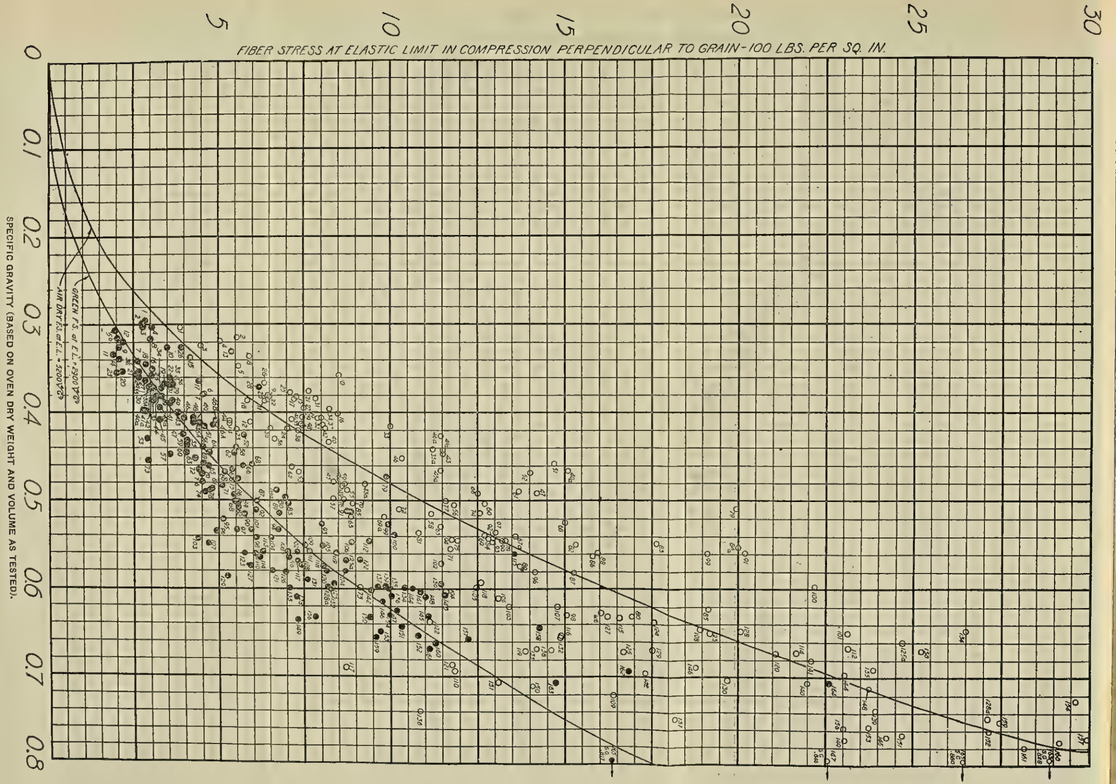
65977°—19. (To back fig. 5.)

FIG. 6.—Relation of shrinkage from green to oven dry conditions to specific gravity.



65977°—19. (To precede page 9.) No. 3.

FIG. 7.—Maximum crushing strength in compression parallel to grain to specific gravity.



53977°—19. (To back fig. 7.)

FIG. 8.—Relation of fiber stress at elastic limit in compression perpendicular to grain to specific gravity.

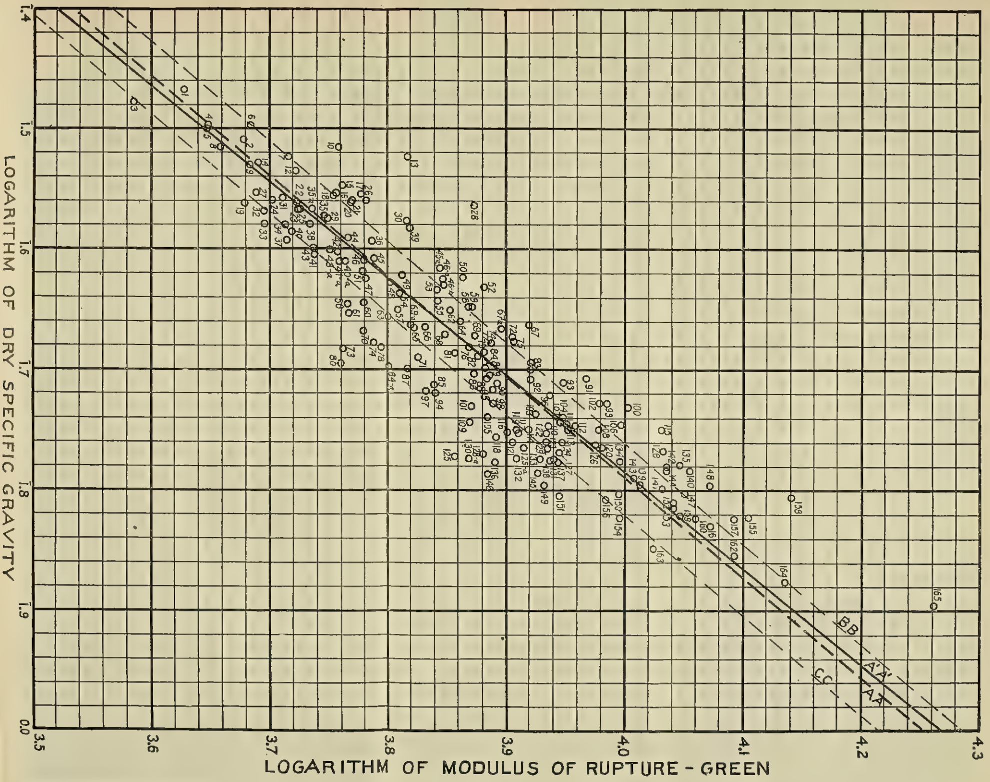

LOGARITHM OF DRY SPECIFIC GRAVITY
1.4
1.5
1.6
1.7
1.8
1.9
0.0
LOGARITHM OF MODULUS OF RUPTURE - GREEN
3.5
3.6
3.7
3.8
3.9
4.0
4.1
4.2
4.3
BB
A'A'
AA
CC

FIG. 9.

APPLICATION OF THE EQUATIONS.

Additional data may possibly necessitate the making of some slight changes in the equations given in Table 1 and the diagrams. However, for comparing species and for determining the best utilization of timber, the value of the equations as they are now is not affected by this possibility. It is to be expected that among a large number of species of widely different structure many will be found which do not satisfy very accurately the average equations connecting the various properties with specific gravity. It is often this variation from an average relation which determines the usefulness of a species for a special purpose.

As an example of the use to which the table and diagrams may be put, suppose it is desired to obtain the strength in compression parallel to the grain of a piece of green hemlock (eastern) grown in the southern Appalachian region. Its specific gravity may be determined by any one of several means which may readily be devised, and we will say that it is found to be 0.38. In the table, the "species-locality" which is probably most nearly representative of the region in question is the eastern hemlock from Tennessee, and of this the maximum crushing strength is 29 per cent above the average for woods of the same specific gravity. To find what an average wood of a specific gravity of 0.38 will stand in compression parallel to the grain, we solve the equation $C=6,900\times0.38$, or turn to figure 1 and read from the curve a maximum crushing strength of about 2,600 pounds per square inch. But since the compressive strength of the Tennessee hemlock was 29 per cent high, it is reasonable to expect that the timber in question will also run about 29 per cent high, or that the value would be about 3,300 or 3,400 pounds per square inch ($2,600\times1.29=3,354$). Any of the other properties of the hemlock under consideration may be estimated in a similar manner.

Again, suppose it is desired to obtain a wood for a use which requires that it be very strong for its weight in its ability to resist a splitting force. Tension perpendicular to grain is the best measure of this. By looking down the column, "Tension, surface of failure radial," it is found that in ability to resist such a force, yellow buckeye is 17 per cent stronger when green and 120 per cent stronger when air-dry than is the average wood of the same specific gravity. It would appear at first that yellow buckeye is the most desirable wood for the purpose, but there is another consideration to be taken into account. Tension perpendicular to the grain varies with the square of the specific gravity; and it must be remembered that those properties (such as tension perpendicular to grain, hardness, work values, and compression perpendicular to the grain) which vary with the higher powers of specific gravity show a large increase in strength with a comparatively small increase in specific gravity. For instance, a wood with twice the specific gravity of another would be expected to have four times as much strength in tension. Yellow buckeye is a very light wood and woods of more than double its specific gravity may easily be found. Such woods, even though they may run somewhat less in tension strength than the average wood of their weight, may have a tension strength considerably in excess of that of yellow buckeye. Thus, the red oaks, having a specific gravity of about twice that of yellow buckeye, are several times as strong in tension perpendicular to the grain, although they are very little above the average wood of their weight in this respect.

It may be seen from these examples that in comparing different timbers or species, in estimating their various properties, and in finding species with exceptional strength in some properties which may render them valuable for special uses, a knowledge of the specific-gravity strength relations is a valuable aid. It must be borne in mind, however, that such equations can never take the place of tests of species whose properties are unknown. If any particular mechanical property is known, the specific gravity may be approximated and the other properties estimated; even the properties of woods upon which no test data are available can be estimated with a fair degree of accuracy from the results of specific gravity determinations. Nevertheless, it is apparent from a study of the table and diagrams that no one kind of test can replace a complete series of tests.

APPENDIX.

METHOD OF DERIVING EQUATIONS.

In plotting the various points to a natural scale (i. e., the shrinkage or a given mechanical property vs. specific gravity) it was found that in many cases they arranged themselves in the form of a curve, or if their trend was along a straight line, this line would not pass through the origin. Assuming that the function should pass through the origin, i. e., that a piece of wood of zero weight or specific gravity should have zero strength, it was found that in practically every case a curve of the form $f=pG^n$ (where f is the strength value, G the specific gravity, and p and n are constants) would fit the points quite well. This equation is the general equation of the parabola of the nth degree passing through the origin.

In order to simplify the determination of the proper values for the constants p and n the equation was transformed into the logarithmic form, $\log f=\log p+n \log G$. This equation represents a straight line having its slope equal to n and its intercept on the y axis equal to $\log p$. Consequently, to find the constants p and n it is only necessary to plot $\log f$ against $\log G$ on ordinary cross-section paper and find the straight line which best averages the points; then n and $\log p$ are determined from the slope and intercept of this line.

To find the straight line which best averages the points in the logarithmic plot the following plan was adopted:

By successive trials the parallel lines BB and CC (see fig. 9) were so located that 25 per cent of the points were above BB and 25 per cent were below CC and at the same time the vertical distance between the two was a minimum. Two lines (not shown on the figure) were then drawn as follows: Both parallel to BB and CC, one bisecting the distance between them and the other in such a position that 50 per cent of the points were on each side of it. AA was then drawn midway between these two lines and assumed to be the line which best averages the points and best represents the relation between specific gravity and the strength property in question. This method, as can readily be seen, is very likely to produce values of n such that the resulting equations can not be handled without the use of logarithms. As the slope of the lines could in most cases be varied through a considerable angle without appreciably affecting the distance between the lines BB and CC, the slope was so taken that n would be a fraction with the denominator 1, 2, 3, or 4. The solution of the equation is then possible by using the rules for the extraction of square and cube roots. Whenever it happened that more than one direction of the lines BB and CC fulfilled the conditions outlined above, preference was given to that slope which would simplify the form of the equation. The constant p was changed at the same time, so that the new line A^1A^1 passed as nearly through the center of gravity of the points as possible.

The analytical process known as the "method of least squares" can be applied to determining the mathematical relations between two properties of a substance as ascertained from experimental results. This method was used in one or two instances to determine the specific gravity strength relations; but it was found that the long and refined computations essential to the application of this method to so large a number of tests was not justified by the added accuracy of the final determinations. Especially is this true since it is desirable to obtain n to the nearest 0.125 only, and since undue refinement in the value of the constant p is unnecessary in view of the fact that there is a considerable variation of actual results from the values given by any equation which may be derived.

TABLE 1.—*Equations and variations—Specific gravity, shrinkage, and strength relations based on tests of small clear pieces, green and air-dry.*

Species and locality.	Reference number.	Specific gravity, oven-dry, based on volume at time of test.	Moisture content.	Shrinkage from green to oven-dry condition.			Static bending.						Impact bending, 50-pound hammer.				Compression parallel to grain.			Compression perpendicular to grain, fiber stress at elastic limit.	Hardness: Load required to embed a 0.444-inch ball one-half its diameter.			Shear.		Cleavage.		Tension.	
				In volume.	Radial.	Tangential.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Work to elastic limit.	Work to maximum load.	Total work.	Fiber stress at elastic limit.	Modulus of elasticity.	Work to elastic limit.	Height of drop causing complete failure.	Fiber stress at elastic limit.	Maximum crushing strength.	Modulus of elasticity.		End surface.	Radial surface.	Tangential surface.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.
			Per cent.	Per cent of dimensions when green.			Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inches.	Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.
I.—EQUATIONS FOR SHRINKAGE AND FOR EACH OF THE STRENGTH PROPERTIES OF GREEN AND AIR-DRY WOOD IN TERMS OF SPECIFIC GRAVITY.																													
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Green..........	.....	.....	.....	.....	.....	.....	$F=10300 \sqrt[4]{G^5}$.	$M=18500 \sqrt[4]{G^5}$.	$E=2500\ G^1$.	$W=3.51\ G^2$.	$W=42.7\ G^2$.	$W=186.0\ G^2$.	$F=23500 \sqrt[4]{G^5}$.	$E=3000\ G^1$.	$W=15.1\ G^2$.	$H=140\ G^2$.	$F=68.0 \sqrt{G^5}$.	$C=6900\ G^1$.	$E=2860\ G^1$.	$F=2900 \sqrt[4]{G^9}$.	$H=3700 \sqrt[4]{G^9}$.	$H=3300 \sqrt[4]{G^9}$.	$H=3300 \sqrt[4]{G^9}$.	$S=2550 \sqrt[3]{G^4}$.	$S=2750 \sqrt[3]{G^4}$.	$C=1070\ G^2$.	$C=1300\ G^2$.	$T=1950\ G^2$.	$T=2300\ G^2$.
Green to oven-dry..	.....	.....	.....	$S=28\ G^1$.	$S=9.5\ G^1$.	$S=17.0\ G^1$.																							
Air-dry..........	.....	.....	.....	.....	.....	.....	$F=19000 \sqrt[4]{G^5}$.	$M=26200 \sqrt[4]{G^5}$.	$E=3000\ G^1$.	$W=9.0\ G^2$.	$W=38.9\ G^2$.	$W=148.0\ G^3$.	$F=35000 \sqrt[4]{G^5}$.	$E=3550\ G^1$.	$W=25\ G^2$.	$H=111\ G^2$.	$F=11000 \sqrt[4]{G^5}$.	$C=12000\ G^1$.	$E=3500\ G^1$.	$F=5200 \sqrt[4]{G^9}$.	$H=4800 \sqrt[4]{G^9}$.	$H=3600 \sqrt[4]{G^9}$.	$H=3800 \sqrt{G^9}$.	$S=3630 \sqrt[3]{G^4}$.	$S=4000 \sqrt[3]{G^4}$.	$C=1100\ G^2$.	$C=1300\ G^2$.	$T=2100\ G^2$.	$T=2400\ G^2$.

II.—MEASURE OF ACCURACY OF RESPECTIVE EQUATIONS.

Proportion of species-locality.	Percentage of equation value.																												
10 per cent above, per cent	.....	.....	.....	119	128	127	123	114	127	139	149	149	118	122	135	142	130	119	133	136	121	121	120	119	117	130	134	135	140
25 per cent above, per cent	.....	.....	.....	110	116	109	112	108	113	117	123	123	110	109	121	118	115	111	117	115	110	111	111	109	109	118	116	118	127
25 per cent below, per cent	.....	.....	.....	90	88	89	91	91	89	86	83	75	90	90	85	86	86	90	86	88	87	88	90	93	89	83	81	80	74
10 per cent below, per cent	.....	.....	.....	80	77	79	79	84	76	72	70	60	84	80	71	76	73	83	72	77	70	78	81	89	83	68	58	55	51
10 per cent above, per cent	.....	.....	.....	.....	.....	.....	126	113	122	164	139	167	130	120	143	145	145	116	142	133	131	124	120	125	122	144	141	139	141
25 per cent above, per cent	.....	.....	.....	.....	.....	.....	111	106	110	135	117	130	112	110	125	120	127	108	120	118	115	111	112	112	110	126	121	127	122
25 per cent below, per cent	.....	.....	.....	.....	.....	.....	85	89	90	75	83	72	85	89	78	83	82	88	86	83	85	94	91	90	88	78	79	69	85
10 per cent below, per cent	.....	.....	.....	.....	.....	.....	75	80	81	60	66	58	73	81	63	70	68	81	67	74	79	83	83	79	78	56	64	54	54

III.—ACTUAL VALUE OF EACH PROPERTY FOR EACH "SPECIES-LOCALITY" AS DETERMINED BY TESTS—EXPRESSED IN PERCENTAGE OF EQUATION VALUE.

Alder, red (Washington):																													
Green	30	.....	.....	119	125	117	122	119	123	139	131	102	119	127	128	117	136	117	138	98	137	119	128	108	110	125	138	139	137
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Ash, Biltmore (Tennessee):																													
Green	91	.....	.....	88	87	80	124	116	104	142	104	88	120	110	130	86	123	114	103	135	121	121	125	124	110	119	109	106	98
Air-dry	.....	.....	.....	.....	.....	.....	131	98	105	160	95	59	117	108	132	132	126	100	100	143	146	135	117	126	98	128	111	130	100
Ash, black (Michigan):																													
Green	60	.....	.....	122	118	103	70	90	100	61	139	144	82	88	81	123	66	76	88	86	100	101	103	100	88	132	86	131	98
Air-dry	.....	.....	.....	.....	.....	.....	128	117	131	92	180	229	.....	.....	.....	174	136	105	115	114	130	114	132	148	106	144	144	124	169
Ash, black (Wisconsin):																													
Green	70	.....	.....	.....	.....	.....	65	84	82	53	142	162	87	69	114	99	.....	91	.....	92	85	92	93	95	83	112	93	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	80	107	94	76	135	177	83	90	88	.....	84	90	93	81	108	102	106	122	100	156	119	144	108
Ash, blue (Kentucky):																													
Green	99	.....	.....	84	77	72	120	113	92	146	121	117	102	87	117	108	115	114	86	144	135	135	138	141	128	96	108	92	101
Air-dry	.....	.....	.....	.....	.....	.....	90	100	82	100	106	129	115	108	123	112	111	97	70	135	135	132	122	112	119	108	112	66	.....

TABLE 1.—*Equations and variations—specific gravity, shrinkage, and strength relations based on tests of small clear pieces, green and air-dry*—Con.

Species and locality.	Reference number.	Specific gravity, oven-dry, based on volume at time of test.	Moisture content.	Shrinkage from green to oven-dry condition.			Static bending.						Impact bending, 50-pound hammer.				Compression parallel to grain.			Compression perpendicular to grain, fiber stress at elastic limit.	Hardness: load required to embed a 0.444-inch ball one-half its diameter.			Shear.		Cleavage.		Tension.	
				In volume.	Radial.	Tangential.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Work to elastic limit.	Work to maximum load.	Total work.	Fiber stress at elastic limit.	Modulus of elasticity.	Work to elastic limit.	Height of drop causing complete failure.	Fiber stress at elastic limit.	Maximum crushing strength.	Modulus of elasticity.		End surface.	Radial surface.	Tangential surface.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.
			Per cent.	Per cent of dimensions when green.			Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inches.	Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.
III.—ACTUAL VALUE OF EACH PROPERTY FOR EACH "SPECIES-LOCALITY" AS DETERMINED BY TESTS—EXPRESSED IN PERCENTAGE OF EQUATION VALUE—Continued.																													
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ash, green (Louisiana):																													
Green	93	.....	.....	80	.....	.....	99	110	102	94	94	77	112	90	137	86	108	113	101	117	107	105	106	118	102	119	99	119	100
Air-dry	.....	.....	.....	.....	.....	.....	98	106	97	104	104	97	91	95	90	90	91	92	95	95	124	121	107	111	93	90	100	111	79
Ash, pumpkin (Missouri):																													
Green	100	.....	.....	87	90	78	128	118	110	139	104	92	108	98	102	92	126	115	101	139	114	118	124	120	109	103	98	100	87
Air-dry	.....	.....	.....	.....	.....	.....	100	105	99	100	106	80	108	108	108	83	105	97	104	135	125	130	112	135	120	159	126	114	87
Ash, white (Missouri):																													
Green	79	.....	.....	88	80	77	107	101	86	130	94	69	90	82	101	92	103	100	80	180	121	119	112	124	112	124	121	125	101
Air-dry	.....	.....	.....	.....	.....	.....	79	88	81	81	67	60	98	93	117	76	85	89	66	172	122	114	107	134	105	174	114	182	98

Ash, white (Arkansas):																													
Green	106	.....	.....	80	82	69	104	111	101	100	151	112	105	95	109	79	109	111	97	119	114	109	117	119	106	100	89	111	98
Air-dry	.....	.....	.....	.....	.....	.....	105	114	106	102	101	122	78	88	69	81	103	98	88	76	130	128	110	120	101	161	100	132	74
Ash, white (West Virginia):																													
Green	83	.....	.....	92	87	79	107	108	103	111	130	115	119	101	140	111	105	99	104	114	123	125	124	121	86	111	117	117	113
Air-dry	.....	.....	.....	.....	.....	.....	106	100	102	119	113	120	115	99	145	111	98	92	100	130	140	126	124	135	100	118	58	150	117
Ash, white (New York):																													
Green	128	.....	.....	82	96	88	116	113	111	108	111	92	114	102	115	99	111	115	103	96	106	112	111	129	119	103	105	106	112
Air-dry	.....	.....	.....	.....	.....	.....	118	105	102	130	104	76	116	108	121	99	137	103	94	106	121	117	126	125	111	109	80	142	98
Aspen (Wisconsin):																													
Green	23	.....	.....	106	96	113	98	99	90	135	117	125	100	96	121	144	86	87	75	72	69	92	93	87	89	72	68	70	55
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Aspen, largetooth (Wisconsin):																													
Green	20	.....	.....	114	92	132	109	111	129	106	106	86	112	107	135	96	115	111	124	96	132	121	124	114	120	130	135	135	144
Air-dry	.....	.....	.....	.....	.....	.....	117	107	135	128	104	128	131	122	166	146	143	110	121	106	114	100	98	104	121	100	131	101	100
Basswood (Pennsylvania):																													
Green	12	.....	.....	171	215	176	105	108	133	98	97	108	106	112	120	104	120	107	152	98	94	95	96	97	100	106	105	103	123
Air-dry	.....	.....	.....	.....	.....	.....	135	115	127	177	177	172	140	136	180	137	165	102	128	85	93	90	97	104	105	161	149	71	150
Basswood (Wisconsin):																													
Green	5	.....	.....	162	206	156	101	101	106	126	135	102	97	97	122	114	73	84	113	96	103	96	93	101	103	115	130	117	132
Air-dry	.....	.....	.....	.....	.....	.....	113	90	157	108	64	91	62	108	51	55	75	93	185	117	108	123	115	150	158	159	194	108	144
Beech (Indiana):																													
Green	110	.....	.....	105	87	111	90	96	96	86	106	81	103	90	108	98	107	91	91	77	104	104	106	98	108	97	130	102	135
Air-dry	.....	.....	.....	.....	.....	.....	78	108	99	67	110	123	92	94	87	98	67	93	97	52	87	98	94	98	96	128	123	132	140
Beech (Pennsylvania):																													
Green	98	.....	.....	105	101	118	95	91	84	100	88	69	83	87	74	92	76	84	80	83	102	95	96	97	100	104	117	106	122
Air-dry	.....	.....	.....	.....	.....	.....	93	90	83	104	73	71	105	101	110	73	90	87	84	82	83	97	94	103	101	90	110	106	50
Birch, paper (Wisconsin):																													
Green	73	.....	.....	116	147	109	70	78	84	59	151	146	82	82	77	137	62	68	71	61	56	77	76	78	78	87	83	92	66
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Birch, sweet (Pennsylvania:																													
Green	129	.....	.....	90	113	76	86	91	102	62	107	86	81	97	62	94	76	88	101	61	88	84	90	94	98	83	86	73	84
Air-dry	.....	.....	.....	.....	.....	.....	119	105	109	121	102	53	132	117	128	106	109	109	150	83	110	103	107	134	120	96	102	.....	61
Birch, yellow (Pennsylvania):																													
Green	107	.....	.....	106	131	94	100	99	107	90	144	125	110	100	115	106	91	92	95	62	83	85	86	93	91	88	88	76	74
Air-dry	.....	.....	.....	.....	.....	.....	105	104	106	102	144	88	119	118	114	142	129	102	82	83	93	104	101	103	118	66	123	55	88
Birch, yellow (Wisconsin):																													
Green	103	.....	.....	111	152	97	86	97	117	59	112	85	96	107	80	81	81	90	123	59	87	91	88	93	86	83	71	72	72
Air-dry	.....	.....	.....	.....	.....	.....	127	118	129	123	119	119	97	109	88	130	121	110	108	76	90	104	97	73	73	96	121	142	123

TABLE 1.—*Equations and variations—specific gravity, shrinkage, and strength relations based on tests of small clear pieces, green and air-dry*—Con.

Species and locality.	Reference number.	Specific gravity, oven-dry, based on volume at time of test.	Moisture content.	Shrinkage from green to oven-dry condition.			Static bending.						Impact bending, 50-pound hammer.				Compression parallel to grain.			Compression perpendicular to grain, fiber stress at elastic limit.	Hardness: load required to embed a 0.444-inch ball one-half its diameter.			Shear.		Cleavage.		Tension.	
				In volume.	Radial.	Tangential.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Work to elastic limit.	Work to maximum load.	Total work.	Fiber stress at elastic limit.	Modulus of elasticity.	Work to elastic limit.	Height of drop causing complete failure.	Fiber stress at elastic limit.	Maximum crushing strength.	Modulus of elasticity.		End surface.	Radial surface.	Tangential surface.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.
			Per cent.	Per cent of dimensions when green.			Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inches.	Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.

III.—ACTUAL VALUE OF EACH PROPERTY FOR EACH "SPECIES-LOCALITY" AS DETERMINED BY TESTS—EXPRESSED IN PERCENTAGE OF EQUATION VALUE—Continued.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Buckeye, yellow (Tennessee):																													
Green	9	.....	.....	127	113	141	99	100	115	100	109	92	105	112	121	112	99	91	106	88	121	110	108	122	112	119	139	117	142
Air-dry	.....	.....	.....	.....	.....	.....	124	92	113	174	110	100	121	107	175	90	128	87	138	182	99	94	96	110	107	128	174	220	182
Buckthorn, cascara (Oregon):																													
Green	84a	.....	.....	54	68	55	77	82	50	117	125	185	85	76	91	157	67	96	70	114	90	112	105	118	95	83	81	101	85
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Butternut (Tennessee):																													
Green	27	.....	.....	109	87	105	91	95	104	94	145	162	119	118	144	148	95	90	85	94	106	108	119	106	119	139	157	167	169
Air-dry	.....	.....	.....	.....	.....	.....	103	81	104	132	156	266	109	122	121	151	128	92	133	117	104	105	119	118	119	102	110	114	151

Butternut (Wisconsin):																													
Green	21	.....	.....	93	107	95	108	113	110	130	149	177	107	110	123	121	115	106	123	90	112	121	121	114	115	154	145	159	159
Air-dry	.....	.....	.....	.....	.....	.....	144	111	111	210	117	.....	130	117	183	130	.....	117	92	130	97	106	110	131	134	121	135	116	125
Chinquapin, western (Oregon):																													
Green	466	.....	.....	112	116	105	119	110	95	169	123	106	110	100	128	126	85	105	128	125	135	137	114	119	124	108	110	137	121
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Cherry, black (Pennsylvania):																													
Green	72	.....	.....	87	82	89	103	111	111	102	135	125	110	105	123	107	111	109	114	86	117	121	112	115	117	119	128	114	130
Air-dry	.....	.....	.....	.....	.....	.....	133	104	101	193	106	71	95	109	86	94	153	111	111	90	154	114	139	110	128	138	81	92	87
Cherry, wild red (Tennessee):																													
Green	24	.....	.....	124	81	168	99	96	115	100	110	137	98	107	105	118	96	87	103	90	110	108	112	93	101	109	106	104	106
Air-dry	.....	.....	.....	.....	.....	.....	126	95	115	174	144	270	106	110	125	196	152	90	100	96	139	119	112	109	106	125	132	87	90
Chestnut (Maryland):																													
Green	46	.....	.....	90	86	97	97	100	93	110	104	114	106	110	108	102	100	97	86	105	108	93	100	117	100	128	125	149	132
Air-dry	.....	.....	.....	.....	.....	.....	112	104	103	142	82	79	90	100	97	85	115	128	102	119	101	108	105	95	85	112	93	113	94
Chestnut (Tennessee):																													
Green	40	.....	.....	118	92	103	90	93	94	100	106	103	104	98	124	107	91	83	86	107	116	105	110	103	89	130	111	123	112
Air-dry	.....	.....	.....	.....	.....	.....	104	87	97	137	86	132	99	87	132	96	108	94	89	104	106	99	96	103	94	133	111	110	127
Cottonwood, black (Washington):																													
Green	6	.....	.....	109	120	161	117	111	135	121	118	149	119	124	144	139	111	99	126	93	101	103	106	100	105	125	146	117	132
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Cucumber tree (Tennessee):																													
Green	59	.....	.....	109	124	118	112	110	140	94	119	101	109	127	100	111	114	103	133	90	93	93	90	105	117	110	112	107	106
Air-dry	.....	.....	.....	.....	.....	.....	133	106	129	144	137	128	126	137	130	144	132	101	143	86	103	93	95	99	111	117	99	123	182
Dogwood, flowering (Tennessee):																													
Green	151	.....	.....	111	116	104	82	84	74	77	121	94	52	43	56	99	.....	83	.....	95	104	118	115	102	103	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	87	76	74	90	83	61	76	75	68	60	76	60	67	87	105	123	114	.....	96	71	101	137	.....
Dogwood, western (Oregon):																													
Green	125a	.....	.....	106	116	97	80	88	75	77	117	89	82	87	71	119	66	91	93	106	112	110	106	98	105	78	86	104	102
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Elder, pale (Oregon):																													
Green	69a	.....	.....	116	99	115	87	94	78	96	97	149	85	88	85	120	95	95	111	99	124	135	135	115	105	139	96	126	108
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Elm, cork (Wisconsin, Marathon County):																													
Green	126	.....	.....	.....	.....	.....	83	101	85	77	137	111	101	79	128	101	.....	94	.....	83	89	93	94	99	101	76	87	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	75	105	93	59	131	113	94	94	91	120	79	94	87	88	90	98	93	107	103	103	114	121	120

TABLE 1.—*Equations and variations—specific gravity, shrinkage, and strength relations based on tests of small clear pieces, green and air-dry*—Con.

III.—ACTUAL VALUE OF EACH PROPERTY FOR EACH "SPECIES-LOCALITY" AS DETERMINED BY TESTS—EXPRESSED IN PERCENTAGE OF EQUATION VALUE—Continued.

Species and locality.	Reference number.	Specific gravity, oven-dry, based on volume at time of test.	Moisture content.	Shrinkage from green to oven-dry condition.			Static bending.						Impact bending, 50-pound hammer.				Compression parallel to grain.			Compression perpendicular to grain, fiber stress at elastic limit.	Hardness: load required to embed a 0.444-inch ball one-half its diameter.			Shear.		Cleavage.		Tension.	
				In volume.	Radial.	Tangential.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Work to elastic limit.	Work to maximum load.	Total work.	Fiber stress at elastic limit.	Modulus of elasticity.	Work to elastic limit.	Height of drop causing complete failure.	Fiber stress at elastic limit.	Maximum crushing strength.	Modulus of elasticity.		End surface.	Radial surface.	Tangential surface.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.
			Per cent.	Per cent of dimensions when green.			Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inches.	Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Elm, cork (Wisconsin, Rusk County):																													
Green	120	.....	.....	89	89	84	93	102	80	100	139	122	90	92	78	108	86	97	84	95	100	108	108	97	97	104	88	97	83
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Elm, slippery (Indiana):																													
Green	102	.....	.....	103	99	107	118	113	98	130	95	126	109	99	115	102	108	106	94	92	112	104	94	110	99	128	115	142	128
Air-dry	.....	.....	.....	.....	.....	.....	84	105	95	76	111	150	92	86	97	105	82	97	83	77	100	112	89	112	109	142	121	127	120
Elm, slippery (Wisconsin):																													
Green	74	.....	.....	100	108	108	92	105	101	90	164	172	94	95	94	156	102	97	95	80	106	108	111	120	106	151	131	143	119
Air-dry	.....	.....	.....	.....	.....	.....	109	100	95	132	154	207	112	100	135	147	111	94	99	108	101	93	104	110	102	95	83	81	45

Elm, white (Pennsylvania):																													
Green	55	.....	.....	112	101	129	103	104	93	121	132	128	96	97	100	126	95	97	102	93	109	106	110	101	106	132	132	135	138
Air-dry	.....	.....	.....	.....	.....	.....	120	107	98	166	137	161	116	92	169	172	115	88	70	85	120	109	114	121	120	121	117	121	98
Elm, white (Wisconsin):																													
Green	53	.....	.....	.....	.....	.....	79	107	97	67	149	142	109	81	146	112	.....	92	.....	69	96	93	100	94	87	96	112	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	95	118	110	94	162	166	108	97	135	147	95	95	126	77	102	106	102	100	110	135	112	137	126
Greenheart:																													
Green	165	.....	.....	57	76	62	179	132	142	174	45	23	131	139	95	44	.....	180	.....	88	69	85	83	87	100	61	51	.....	50
Air-dry	.....	.....	.....	.....	.....	.....	126	105	128	100	55	35	96	117	64	56	116	117	127	67	49	72	65	62	51	.....	.....	.....	.....
Gum, black (Tennessee):																													
Green	68	.....	.....	105	100	98	101	98	88	117	85	77	105	95	117	94	94	95	72	119	112	106	102	105	116	119	123	117	121
Air-dry	.....	.....	.....	.....	.....	.....	108	78	80	154	51	77	110	96	132	64	82	83	81	122	114	100	90	89	92	86	115	79	76
Gum, blue (California):																													
Green	147	.....	.....	130	127	143	129	107	126	114	81	68	107	128	79	71	129	121	128	100	102	123	114	98	116	71	80	63	88
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Gum, cotton (Louisiana):																													
Green	76	.....	.....	93	97	98	104	100	87	122	79	80	83	92	73	77	86	108	94	81	113	106	117	103	105	108	130	108	152
Air-dry	.....	.....	.....	.....	.....	.....	76	80	84	76	53	58	74	83	73	61	80	99	85	79	114	106	103	98	109	130	112	82	122
Gum, red (Missouri):																													
Green	54	.....	.....	.....	.....	.....	95	99	105	.....	.....	.....	.....	.....	.....	.....	113	90	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Hackberry (Indiana):																													
Green	90	.....	.....	101	88	104	74	96	97	59	174	166	109	96	123	146	95	96	74	92	104	114	110	111	109	157	142	144	142
Air-dry	.....	.....	.....	.....	.....	.....	81	109	87	79	156	149	105	98	115	193	83	97	90	100	121	126	121	104	104	95	115	101	104
Hackberry (Wisconsin):																													
Green	78	.....	.....	103	106	109	69	84	76	71	136	129	77	74	80	137	71	76	67	81	103	106	108	106	105	121	114	124	121
Air-dry	.....	.....	.....	.....	.....	.....	77	83	75	85	97	130	95	79	117	113	82	78	58	100	92	90	97	103	108	86	91	66	94
Haw, pear (Wisconsin):																													
Green	146	.....	.....	.....	.....	.....	70	76	63	66	142	114	.....	.....	.....	.....	.....	72	.....	100	95	108	104	96	96	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	76	85	67	79	130	69	62	76	46	39	68	78	52	85	104	101	105	88	.....	.....	.....	.....	.....
Hickory, big shellbark (Mississippi):																													
Green	135	.....	.....	.....	.....	.....	117	113	103	114	156	164	111	98	114	156	100	87	97	108	.....	.....	.....	88	85	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	85	100	96	70	112	128	116	107	125	137	.....	85	.....	106	.....	.....	.....	107	112	.....	.....	.....	.....
Hickory, big shellbark (Ohio):																													
Green	154	.....	.....	.....	.....	.....	77	89	66	79	190	161	101	74	117	210	48	73	68	96	.....	.....	.....	74	83	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	68	96	90	40	100	.....	.....	88	.....	138	.....	96	.....	117	.....	.....	.....	92	73	.....	.....	.....	.....
Hickory, bitternut (Ohio):																													
Green	139	.....	.....	.....	.....	.....	96	100	90	88	120	142	130	94	162	135	120	110	94	108	.....	.....	.....	91	99	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	85	99	90	74	94	152	123	120	122	132	.....	107	.....	90	.....	.....	.....	95	.....	.....	.....	.....	.....

TABLE 1.—*Equations and variations—specific gravity, shrinkage, and strength relations based on tests of small clear pieces, green and air-dry*—Con.

Species and locality.	Reference number.	Specific gravity, oven-dry, based on volume at time of test.	Moisture content.	Shrinkage from green to oven-dry condition.			Static bending.						Impact bending, 50-pound hammer.				Compression parallel to grain.			Compression perpendicular to grain, fiber stress at elastic limit.	Hardness: load required to embed a 0.444-inch ball one-half its diameter.			Shear.		Cleavage.		Tension.	
				In volume.	Radial.	Tangential.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Work to elastic limit.	Work to maximum load.	Total work.	Fiber stress at elastic limit.	Modulus of elasticity.	Work to elastic limit.	Height of drop causing complete failure.	Fiber stress at elastic limit.	Maximum crushing strength.	Modulus of elasticity.		End surface.	Radial surface.	Tangential surface.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.
			Per cent.	Per cent of dimensions when green.			Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inches.	Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.
III.—ACTUAL VALUE OF EACH PROPERTY FOR EACH "SPECIES-LOCALITY" AS DETERMINED BY TESTS—EXPRESSED IN PERCENTAGE OF EQUATION VALUE—Continued.																													
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Hickory, mockernut (Mississippi):																													
Green	144	.....	.....	.....	.....	.....	107	110	107	94	118	119	126	104	142	98	98	109	96	117	.....	.....	.....	98	107	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	108	110	104	104	101	123	90	106	81	90	.....	102	.....	100	.....	.....	.....	89	83	.....	.....	.....	.....
Hickory, mockernut (Pennsylvania):																													
Green	159	.....	.....	.....	.....	.....	106	101	91	96	168	135	110	102	103	196	98	94	72	85	.....	.....	.....	87	84	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	100	94	107	72	98	114	83	88	65	118	.....	89	.....	96	.....	.....	.....	.....	.....	.....	.....	.....	.....
Hickory, mockernut (West Virginia):																													
Green	155	.....	.....	.....	.....	.....	111	114	113	90	127	156	.....	.....	.....	.....	130	116	80	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Hickory, nutmeg (Mississippi):																													
Green	112	....	....	....	....	....	97	101	92	96	169	149	115	88	138	130	111	104	89	125	....	....	....	90	86	....	....	....	....
Air-dry	....	....	....	....	....	....	88	110	98	72	172	....	....	....	....	....	....	89	....	109	....	....	....	110	....	....	....	....	....
Hickory, pignut (Mississippi):																													
Green	148	....	....	....	....	....	112	114	106	102	145	121	114	88	125	150	92	113	82	114	....	....	....	79	74	....	....	....	....
Air-dry	....	....	....	....	....	....	100	111	115	79	114	114	113	112	110	107	....	98	....	100	....	....	....	....	102	....	....	....	....
Hickory, pignut (Ohio):																													
Green	157	....	....	....	....	....	110	110	93	108	144	140	105	72	138	182	102	105	90	108	....	....	....	93	113	....	....	....	....
Air-dry	....	....	....	....	....	....	87	106	110	67	101	122	107	123	87	152	....	92	....	102	....	....	....	125	115	....	....	....	....
Hickory, pignut (Pennsylvania):																													
Green	160	....	....	....	....	....	99	103	96	86	182	138	112	97	112	149	105	105	100	98	....	....	....	87	87	....	....	....	....
Air-dry	....	....	....	....	....	....	91	103	100	69	137	139	103	104	90	100	....	99	....	100	....	....	....	85	78	....	....	....	....
Hickory, pignut (West Virginia):																													
Green	161	....	....	....	....	....	92	104	104	69	156	132	131	95	146	110	87	104	104	94	....	....	....	86	87	....	....	....	....
Air-dry	....	....	....	....	....	....	94	94	103	77	128	....	....	115	....	92	....	93	....	94	....	....	....	90	85	....	....	....	....
Hickory, shagbark (Mississippi):																													
Green	140	....	....	....	....	....	112	114	107	102	106	130	111	95	115	97	115	121	108	121	....	....	....	90	91	....	....	....	....
Air-dry	....	....	....	....	....	....	94	103	102	81	97	128	93	100	85	113	....	99	....	92	....	....	....	122	112	....	....	....	....
Hickory, shagbark (Ohio):																													
Green	152	....	....	....	....	....	91	103	83	86	190	149	92	84	88	174	73	98	81	96	....	....	....	94	99	....	....	....	....
Air-dry	....	....	....	....	....	....	76	107	95	51	137	....	....	97	....	119	....	96	....	96	....	....	....	....	81	....	....	....	....
Hickory, shagbark (Pennsylvania):																													
Green	143	....	....	....	....	....	104	100	90	121	74	146	....	....	....	....	76	103	59	....	....	....	....	....	87	....	....	....	....
Air-dry	....	....	....	....	....	....	120	115	93	163	94	....	....	....	....	....	....	95	....	94	....	....	....	....	....	....	....	....	....
Hickory, shagbark (West Virginia):																													
Green	153	....	....	....	....	....	101	101	107	81	100	121	114	100	110	98	95	103	105	88	....	....	....	84	82	....	....	....	....
Air-dry	....	....	....	....	....	....	98	106	108	77	114	....	101	106	87	106	....	103	....	86	....	....	....	94	93	....	....	....	....
Hickory, water (Mississippi):																													
Green	141	....	....	....	....	....	103	103	99	92	111	98	104	93	102	101	90	112	111	117	....	....	....	102	101	....	....	....	....
Air-dry	....	....	....	....	....	....	105	111	111	93	117	110	....	107	....	106	....	109	....	100	....	....	....	....	80	....	....	....	....
Holly, American (Tennessee):																													
Green	87	....	....	114	94	111	78	84	71	81	100	114	89	70	116	144	69	76	60	100	112	114	119	98	114	102	132	95	128
Air-dry	....	....	....	....	....	....	81	72	69	95	77	40	85	77	104	76	76	73	62	100	121	102	110	98	128	113	....	132	74
Hornbeam (Tennessee):																													
Green	149	....	....	107	135	89	79	83	74	74	80	76	78	94	56	126	69	82	75	71	76	88	85	94	94	72	62	56	47
Air-dry	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Laurel, mountain (Tennessee):																													
Green	145	....	....	81	95	84	104	85	60	154	79	58	76	59	86	57	....	101	....	108	112	117	118	116	113	....	....	....	....
Air-dry	....	....	....	....	....	....	88	62	66	105	46	30	75	71	71	79	72	65	62	85	112	128	119	....	....	....	....	....	....

TABLE 1.—*Equations and variations—specific gravity, shrinkage, and strength relations based on tests of small clear pieces, green and air-dry*—Con.

Species and locality.	Reference number.	Specific gravity, oven-dry, based on volume at time of test.	Moisture content.	Shrinkage from green to oven-dry condition.			Static bending.						Impact bending, 50-pound hammer.				Compression parallel to grain.			Compression perpendicular to grain, fiber stress at elastic limit.	Hardness: load required to embed a 0.444-inch ball one-half its diameter.			Shear.		Cleavage.		Tension.	
				In volume.	Radial.	Tangential.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Work to elastic limit.	Work to maximum load.	Total work.	Fiber stress at elastic limit.	Modulus of elasticity.	Work to elastic limit.	Height of drop causing complete failure.	Fiber stress at elastic limit.	Maximum crushing strength.	Modulus of elasticity.		End surface.	Radial surface.	Tangential surface.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.
			Per cent.	Per cent of dimensions when green.			Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inches.	Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.
III.—ACTUAL VALUE OF EACH PROPERTY FOR EACH "SPECIES-LOCALITY" AS DETERMINED BY TESTS—EXPRESSED IN PERCENTAGE OF EQUATION VALUE—Continued.																													
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Locust, black (Tennessee):																													
Green	158	.....	.....	55	70	62	148	130	115	164	88	80	130	120	121	73	155	149	102	130	100	102	114	133	100	71	83	88	83
Air-dry	.....	.....	.....	.....	.....	.....	115	113	101	124	102	125	97	105	84	110	111	117	168	119	61	86	93	107	123	58	55	63	52
Locust, honey (Indiana):																													
Green	162	.....	.....	46	.....	.....	88	101	96	71	79	83	87	99	61	76	100	104	78	132	114	128	125	115	119	96	92	114	123
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Madrona (California):																													
Green	101	.....	.....	108	101	128	98	87	79	111	64	40	74	88	58	68	85	87	66	85	105	94	94	106	103	112	94	112	106
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Madrona (Oregon):																													
Green	128a	.....	.....	108	99	120	88	80	57	121	81	45	87	70	97	85	66	83	78	91	108	103	99	113	110	106	104	104	102
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Magnolia (Louisiana):																													
Green	66	.....	.....	95	123	85	92	96	90	88	167	154	100	102	103	186	86	85	98	112	119	128	125	110	115	113	157	121	156
Air-dry	.....	.....	.....	.....	.....	.....	96	96	97	104	121	72	101	95	118	90	83	85	127	190	132	135	132	124	100	190	119	135	138
Maple, Oregon (Washington):																													
Green	58	.....	.....	91	89	95	117	110	98	146	103	72	99	110	93	84	98	107	99	121	130	121	121	122	123	126	144	132	151
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Maple, red (Pennsylvania):																													
Green	69	.....	.....	95	86	103	94	103	118	76	120	96	110	107	118	104	97	97	119	90	114	108	110	109	120	119	139	122	132
Air-dry	.....	.....	.....	.....	.....	.....	113	104	109	130	121	135	107	110	112	100	114	97	91	98	117	102	99	122	135	139	149	66	104
Maple, red (Wisconsin):																													
Green	92	.....	.....	.....	.....	.....	100	104	113	85	88	55	119	95	146	83	.....	104	.....	100	90	85	85	106	115	99	94	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	93	106	104	84	98	80	103	97	113	94	98	101	98	98	114	101	102	104	106	135	130	102	135
Maple, silver (Wisconsin):																													
Green	56	.....	.....	96	72	97	83	87	85	88	132	107	82	80	92	110	81	82	86	100	112	112	112	116	124	132	132	133	149
Air-dry	.....	.....	.....	.....	.....	.....	112	82	85	133	86	91	110	86	171	100	128	87	68	106	145	100	109	118	129	132	137	69	125
Maple, sugar (Indiana):																													
Green	104	.....	.....	93	94	98	95	101	106	83	98	85	105	103	102	90	96	97	94	90	103	108	110	105	119	112	132	106	126
Air-dry	.....	.....	.....	.....	.....	.....	100	103	100	103	85	81	84	95	76	74	87	100	95	59	123	112	114	111	130	100	95	52	108
Maple, sugar (Pennsylvania):																													
Green	108	.....	.....	92	91	97	114	105	108	111	100	92	106	96	110	93	98	101	84	90	108	108	108	107	115	108	117	104	128
Air-dry	.....	.....	.....	.....	.....	.....	107	95	90	122	89	64	116	112	116	89	117	101	80	98	114	114	116	132	132	108	154	104	74
Maple, sugar (Wisconsin):																													
Green	124	.....	.....	.....	.....	.....	89	95	99	72	68	38	120	94	142	63	.....	103	.....	104	89	86	85	109	115	95	104	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	86	104	103	70	90	62	94	94	94	73	90	101	98	92	112	104	107	108	110	140	138	.....	.....
Oak, bur (Wisconsin):																													
Green	125	.....	.....	77	80	90	68	75	59	71	72	67	79	66	85	85	68	82	52	102	100	108	110	98	101	95	97	100	106
Air-dry	.....	.....	.....	.....	.....	.....	62	63	54	71	56	45	74	66	79	56	58	76	59	79	72	94	94	80	95	45	72	48	83
Oak, California black (California):																													
Green	80	.....	.....	103	88	77	75	75	63	92	71	42	84	84	83	80	64	75	66	116	106	108	106	96	91	108	113	109	119
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oak, canyon live (California):																													
Green	163	.....	.....	82	119	119	95	88	76	94	67	46	75	86	55	71	93	97	78	110	96	108	105	100	109	81	100	83	108
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oak, chestnut (Tennessee):																													
Green	121	.....	.....	106	101	100	90	87	95	77	67	53	99	101	89	73	86	91	94	77	90	96	92	93	94	81	102	86	102
Air-dry	.....	.....	.....	.....	.....	.....	93	81	82	97	66	53	101	119	83	87	79	81	98	53	67	81	77	65	79	45	95	.....	142
Oak, cow (Louisiana):																													
Green	133	.....	.....	114	104	91	90	88	91	80	85	76	84	106	61	90	87	87	89	77	96	110	109	91	98	83	102	85	93
Air-dry	.....	.....	.....	.....	.....	.....	65	87	90	44	68	49	86	105	66	76	65	88	92	115	64	85	79	98	86	45	71	56	68

TABLE 1.—*Equations and variations—specific gravity, shrinkage, and strength relations based on tests of small clear pieces, green and air-dry*—Con.

Species and locality.	Reference number.	Specific gravity, oven-dry, based on volume at time of test.	Moisture content.	Shrinkage from green to oven-dry condition.			Static bending.						Impact bending, 50-pound hammer.				Compression parallel to grain.			Compression perpendicular to grain, fiber stress at elastic limit.	Hardness: load required to embed a 0.444-inch ball one-half its diameter.			Shear.		Cleavage.		Tension.	
				In volume.	Radial.	Tangential.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Work to elastic limit.	Work to maximum load.	Total work.	Fiber stress at elastic limit.	Modulus of elasticity.	Work to elastic limit.	Height of drop causing complete failure.	Fiber stress at elastic limit.	Maximum crushing strength.	Modulus of elasticity.		End surface.	Radial surface.	Tangential surface.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.
			Per cent.	Per cent of dimensions when green.			Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inches.	Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.
III.—ACTUAL VALUE OF EACH PROPERTY FOR EACH "SPECIES-LOCALITY" AS DETERMINED BY TESTS—EXPRESSED IN PERCENTAGE OF EQUATION VALUE—Continued.																													
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Oak, laurel (Louisiana):																													
Green	116			119	73	99	89	88	98	76	83	61	90	108	72	89	82	81	94	88	102	112	110	96	97	92	109	104	126
Air-dry							77	78	89	64	70	91	78	106	60	91	83	87	117	130	71	95	92	95	104	77	73	83	95
Oak, post (Arkansas):																													
Green	130			93	101	105	88	76	61	110	60	38	89	88	79	74	80	82	63	125	97	102	104	91	99	86	101	100	108
Air-dry							68	74	66	66	56	45	72	81	59	80	51	77	77	85	72	96	84	83	72	74	76	55	90
Oak, post (Louisiana):																													
Green	137			95	91	87	96	90	84	97	86	64	84	95	67	95	81	87	83	106	100	116	112	93	93	89	94	92	102
Air-dry							62	81	82	43	83	128	90	83	87	95	66	82	97	132	62	100	81	82	85	55	92	54	85
Oak, red (Arkansas):																													
Green	119			91	78	86	77	89	88	63	94	101	93	92	87	94	76	88	82	107	110	114	114	101	94	102	107	106	118
Air-dry							98	92	105	92	81	120	92	92	88	93	69	99	128	66	92	110	112	102	102	85	110	108	136

Oak, red (Indiana):																													
Green	118	.....	.....	82	69	87	68	85	89	52	83	62	91	89	86	80	69	82	80	98	108	110	108	94	94	105	112	102	119
Air-dry	.....	.....	.....	.....	.....	.....	60	85	90	40	77	71	85	83	85	71	51	77	89	69	81	93	100	87	89	72	77	59	96
Oak, red (Louisiana):																													
Green	117	.....	.....	.....	.....	.....	86	90	104	66	72	64	89	107	68	89	81	89	119	85	96	104	104	88	82	102	100	110	107
Air-dry	.....	.....	.....	.....	.....	.....	77	89	98	55	74	66	113	103	116	102	83	87	92	36	112	83	77	77	78	107	104	.....	.....
Oak, red (Tennessee):																													
Green	97	.....	.....	103	74	92	70	83	90	56	103	100	95	95	91	121	60	74	82	79	100	112	107	92	90	116	115	114	121
Air-dry	.....	.....	.....	.....	.....	.....	82	90	95	72	100	130	101	111	93	119	97	88	80	71	85	98	90	93	83	50	92	85	92
Oak, highland Spanish (Louisiana):																													
Green	94	.....	.....	112	91	98	91	84	86	94	68	46	90	100	79	80	73	84	92	96	100	104	110	97	76	101	83	95	79
Air-dry	.....	.....	.....	.....	.....	.....	63	76	86	48	67	46	88	82	90	65	53	82	179	111	71	102	95	59	96	68	95	55	71
Oak, lowland Spanish (Louisiana):																													
Green	142	.....	.....	99	90	104	117	110	118	102	94	78	95	123	66	100	103	111	117	100	106	121	117	96	94	93	104	91	104
Air-dry	.....	.....	.....	.....	.....	.....	100	107	113	82	101	72	114	113	110	93	101	101	117	132	76	94	94	95	92	64	72	74	85
Oak, swamp white (Indiana):																													
Green	150	.....	.....	96	92	98	92	94	100	74	85	68	97	106	76	85	90	99	82	92	88	100	91	85	91	90	99	93	101
Air-dry	.....	.....	.....	.....	.....	.....	80	103	95	61	95	103	89	92	77	80	74	94	85	59	69	90	90	72	82	66	76	56	.....
Oak, tanbark (California):																													
Green	115	.....	.....	.....	.....	.....	130	119	119	.....	.....	.....	.....	.....	.....	.....	147	125	.....	169	.....	.....	.....	.....	.....	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	85	105	110	.....	.....	.....	.....	.....	.....	.....	.....	108	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oak, water (Louisiana):																													
Green	111	.....	.....	102	80	98	112	100	111	104	85	79	100	120	80	88	98	98	111	98	106	116	114	101	100	104	101	105	135
Air-dry	.....	.....	.....	.....	.....	.....	86	101	108	53	142	92	95	107	81	93	62	86	150	115	81	95	85	96	90	79	102	92	101
Oak, white (Arkansas):																													
Green	132	.....	.....	95	109	82	80	84	77	76	81	79	84	83	78	89	68	86	56	89	92	96	87	91	99	104	108	99	100
Air-dry	.....	.....	.....	.....	.....	.....	66	82	80	52	66	66	67	76	55	55	46	86	47	74	98	99	106	88	94	85	88	44	108
Oak, white (Indiana):																													
Green	138	.....	.....	86	85	88	88	89	88	93	87	76	87	87	77	87	88	85	76	77	93	100	100	91	100	83	106	89	119
Air-dry	.....	.....	.....	.....	.....	.....	62	100	92	44	72	45	84	100	66	52	76	103	82	69	72	95	89	103	103	77	97	72	99
Oak, white (Richland Parish, Louisiana):																													
Green	136	.....	.....	96	84	90	81	80	80	74	58	41	94	82	95	69	85	84	69	106	97	108	105	88	98	92	102	89	119
Air-dry	.....	.....	.....	.....	.....	.....	73	91	84	58	79	58	78	90	64	79	67	82	66	41	69	93	84	79	91	51	107	27	87
Oak, white (Winn Parish, Louisiana):																													
Green	131	.....	.....	99	96	94	101	90	90	100	79	55	84	103	61	92	96	91	99	86	96	104	101	94	93	88	104	94	108
Air-dry	.....	.....	.....	.....	.....	.....	75	89	87	60	98	69	85	82	76	100	63	82	120	110	66	81	68	86	93	50	85	54	102
Oak, willow (Louisiana):																													
Green	109	.....	.....	120	94	101	88	84	93	81	67	55	84	102	66	85	76	78	88	100	96	104	103	100	102	116	112	117	126
Air-dry	.....	.....	.....	.....	.....	.....	83	79	93	67	77	85	75	90	113	77	67	78	122	119	56	69	90	57	88	.....	128	.....	113

TABLE 1.—*Equations and variations—specific gravity, shrinkage, and strength relations based on tests of small clear pieces, green and air-dry*—Con.

Species and locality.	Reference number.	Specific gravity, oven-dry, based on volume at time of test.	Moisture content.	Shrinkage from green to oven-dry condition.			Static bending.						Impact bending, 50-pound hammer.				Compression parallel to grain.			Compression perpendicular to grain, fiber stress at elastic limit.	Hardness: load required to embed a 0.444-inch ball one-half its diameter.			Shear.		Cleavage.		Tension.	
				In volume.	Radial.	Tangential.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Work to elastic limit.	Work to maximum load.	Total work.	Fiber stress at elastic limit.	Modulus of elasticity.	Work to elastic limit.	Height of drop causing complete failure.	Fiber stress at elastic limit.	Maximum crushing strength.	Modulus of elasticity.		End surface.	Radial surface.	Tangential surface.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.
			Per cent.	Per cent of dimensions when green.			Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inches.	Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.
III.—ACTUAL VALUE OF EACH PROPERTY FOR EACH "SPECIES-LOCALITY" AS DETERMINED BY TESTS—EXPRESSED IN PERCENTAGE OF EQUATION VALUE—Continued.																													
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Oak, yellow (Arkansas):																													
Green	122	.....	.....	88	83	100	100	94	86	105	85	76	94	88	92	98	85	94	90	112	100	112	106	98	91	107	114	119	128
Air-dry	.....	.....	.....	.....	.....	.....	71	89	86	57	82	83	73	85	63	116	80	84	90	59	83	110	96	95	97	81	94	85	.....
Oak, yellow (Wisconsin):																													
Green	105	.....	.....	.....	.....	.....	75	87	81	66	102	95	108	74	150	88	.....	81	.....	110	86	92	90	110	105	98	92	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	83	105	92	73	102	90	88	89	87	83	82	95	88	76	108	110	105	120	112	121	123	120	119
Osage orange (Indiana):																													
Green	164	.....	.....	42	.....	.....	107	105	70	126	156	117	90	64	95	138	83	111	62	172	92	131	100	.....	.....	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Poplar, yellow (tulip tree) (Tennessee):																													
Green	35	.....	.....	110	116	110	104	103	129	97	94	66	115	122	122	86	102	99	144	100	102	96	94	102	116	125	166	128	180
Air-dry	.....	.....	.....	.....	.....	.....	129	99	127	159	108	100	158	142	202	114	123	102	171	102	88	83	92	96	100	144	149	118	164
Rhododendron, great (Tennessee):																													
Green	85	.....	.....	114	132	102	102	85	67	147	107	101	.....	65	.....	69	.....	100	.....	135	123	123	120	110	112	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	86	77	72	100	92	71	50	67	36	40	90	81	81	107	.....	.....	.....	.....	.....	84	66	99	119
Sassafras (Tennessee):																													
Green	51	.....	.....	87	99	86	104	97	88	130	96	128	104	92	127	146	104	93	72	113	122	122	114	121	103	151	126	149	125
Air-dry	.....	.....	.....	.....	.....	.....	105	86	88	142	112	216	87	83	113	132	89	81	67	164	86	123	112	108	94	122	112	149	110
Serviceberry Tennessee):																													
Green	156	.....	.....	104	107	96	95	90	102	74	92	71	87	106	62	103	80	90	81	76	88	99	99	79	86	72	81	81	79
Air-dry	.....	.....	.....	.....	.....	.....	101	88	88	98	90	95	98	103	85	90	108	91	61	83	79	89	83	64	84	.....	.....	.....	.....
Silverbell-tree (Tennessee):																													
Green	49	.....	.....	109	95	107	101	104	111	100	117	103	113	111	124	109	93	98	104	108	102	98	98	112	110	128	135	117	130
Air-dry	.....	.....	.....	.....	.....	.....	98	80	99	112	69	81	113	106	135	90	101	86	118	85	108	86	90	91	90	110	132	93	90
Sourwood (Tennessee):																													
Green	89	.....	.....	108	131	104	100	96	103	90	88	68	107	104	107	106	94	93	130	104	106	101	102	106	110	128	132	131	136
Air-dry	.....	.....	.....	.....	.....	.....	110	80	92	123	83	83	116	98	137	103	104	87	192	91	114	98	94	105	77	106	79	50	55
Sumac, staghorn (Wisconsin):																													
Green	61	.....	.....	.....	.....	.....	79	85	72	93	123	190	.....	.....	.....	.....	.....	87	.....	101	112	110	110	.....	.....	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	131	89	90	203	80	95	.....	.....	.....	.....	129	99	85	132	110	120	100	.....	.....	.....	.....	.....	.....
Sycamore (Indiana):																													
Green	63	.....	.....	106	115	95	74	91	85	71	81	61	93	86	104	85	92	89	83	88	112	107	114	102	115	116	159	137	166
Air-dry	.....	.....	.....	.....	.....	.....	71	84	91	64	66	45	62	74	54	46	77	88	95	76	86	95	98	80	88	77	126	85	110
Sycamore (Tennessee):																													
Green	65	.....	.....	112	119	102	94	94	100	92	86	72	101	105	101	93	96	97	100	91	106	106	104	97	105	112	125	107	146
Air-dry	.....	.....	.....	.....	.....	.....	109	86	103	119	107	92	62	97	44	112	103	84	106	92	87	85	101	76	.....	.....	.....	.....	.....
Umbrella, Fraser (Tennessee):																													
Green	45	.....	.....	112	115	110	100	102	117	95	118	98	112	118	119	100	104	95	115	85	118	114	121	104	103	130	132	125	135
Air-dry	.....	.....	.....	.....	.....	.....	126	94	107	166	125	119	125	126	142	121	123	91	144	85	112	108	104	94	105	142	144	159	174
Willow, black (Wisconsin):																													
Green	11	.....	.....	134	70	147	52	71	58	67	269	237	105	55	104	272	54	58	54	77	94	114	121	86	93	154	156	161	185
Air-dry	.....	.....	.....	.....	.....	.....	89	77	57	207	174	149	80	68	130	118	73	68	46	102	110	116	110	124	128	144	161	122	143
Willow, western black (Oregon):																													
Green	43a	.....	.....	120	77	134	95	95	102	102	157	154	100	110	101	144	86	86	119	92	110	128	128	105	112	110	101	99	106
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Witch hazel (Tennessee):																													
Green	114	.....	.....	116	.....	.....	100	92	79	114	144	142	104	79	123	85	.....	88	.....	77	100	106	111	86	88	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	94	82	76	102	104	.....	.....	.....	.....	.....	101	74	95	101	121	128	117	.....	.....	.....	.....	.....	.....

TABLE 1.—*Equations and variations—specific gravity, shrinkage, and strength relations based on tests of small clear pieces, green and air-dry*—Con.

Species and locality.	Reference number.	Specific gravity, oven-dry, based on volume at time of test.	Moisture content.	Shrinkage from green to oven-dry condition. In volume.	Shrinkage from green to oven-dry condition. Radial.	Shrinkage from green to oven-dry condition. Tangential.	Static bending. Fiber stress at elastic limit.	Static bending. Modulus of rupture.	Static bending. Modulus of elasticity.	Static bending. Work to elastic limit.	Static bending. Work to maximum load.	Static bending. Total work.	Impact bending, 50-pound hammer. Fiber stress at elastic limit.	Impact bending, 50-pound hammer. Modulus of elasticity.	Impact bending, 50-pound hammer. Work to elastic limit.	Impact bending, 50-pound hammer. Height of drop causing complete failure.	Compression parallel to grain. Fiber stress at elastic limit.	Compression parallel to grain. Maximum crushing strength.	Compression parallel to grain. Modulus of elasticity.	Compression perpendicular to grain, fiber stress at elastic limit.	Hardness: load required to embed a 0.444-inch ball one-half its diameter. End surface.	Hardness: load required to embed a 0.444-inch ball one-half its diameter. Radial surface.	Hardness: load required to embed a 0.444-inch ball one-half its diameter. Tangential surface.	Shear. Surface of failure radial.	Shear. Surface of failure tangential.	Cleavage. Surface of failure radial.	Cleavage. Surface of failure tangential.	Tension. Surface of failure radial.	Tension. Surface of failure tangential.
			Per cent.	Per cent of dimensions when green.			Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inches.	Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.

III.—ACTUAL VALUE OF EACH PROPERTY FOR EACH "SPECIES-LOCALITY" AS DETERMINED BY TESTS—EXPRESSED IN PERCENTAGE OF EQUATION VALUE—Continued.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
CONIFERS.																													
Cedar, incense (California):																													
Green	26	......	......	......	......	......	136	115	83	......	......	......	......	......	......	......	159	121	......	......	......	......	......	......	......	......	......	......	......
Air-dry	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Cedar, western red (Montana):																													
Green	2	......	......	90	89	92	114	105	109	146	100	83	116	123	139	119	157	130	117	142	164	110	119	132	118	130	99	114	98
Air-dry	......	......	......	......	......	......	106	93	115	125	100	128	116	130	144	86	193	119	163	144	154	100	119	99	100	90	67	72	85
Cedar, western red (Washington):																													
Green	10	......	......	93	80	101	140	124	124	190	121	110	133	121	180	121	160	135	135	149	159	104	108	128	119	112	92	100	76
Air-dry	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

Cedar, white (Wisconsin):																													
Green	1	.....	.....	85	75	95	115	106	87	196	156	132	105	90	161	128	97	98	90	151	110	88	88	126	115	156	128	149	121
Air-dry	.....	.....	.....	.....	.....	.....	120	110	90	228	130	144	95	100	128	126	107	102	93	108	114	106	117	119	123	142	145	121	128
Cypress, bald (Louisiana):																													
Green	62	.....	.....	91	89	78	117	105	123	135	59	71	94	106	88	81	141	127	134	115	77	67	67	95	84	72	59	61	53
Air-dry	.....	.....	.....	.....	.....	.....	111	115	120	135	88	144	75	85	74	88	135	138	134	78	91	84	88	76	57	50	56	41	35
Douglas fir (California):																													
Green	45a	.....	.....	102	118	102	126	114	133	128	85	72	113	130	110	92	127	123	182	114	101	98	101	102	95	61	53	67	62
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Douglas fir (Oregon):																													
Green	67a	.....	.....	101	129	97	123	111	144	105	76	76	107	127	93	88	132	128	180	104	81	83	90	93	89	39	38	26	42
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Douglas fir (Chehalis County, Washington):																													
Green	46a	.....	.....	108	111	105	122	111	133	117	81	86	107	131	97	85	127	119	167	121	95	92	97	117	102	66	69	46	58
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Douglas fir (Lewis County, Washington):																													
Green	75	.....	.....	93	110	103	130	110	136	121	71	83	101	126	83	83	140	126	165	101	74	77	83	96	89	62	58	49	49
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Douglas fir (Washington and Oregon):																													
Green	67	.....	.....	.....	.....	.....	133	118	138	.....	.....	.....	.....	.....	.....	.....	.....	127	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Douglas fir (Wyoming):																													
Green	48	.....	.....	95	92	93	107	100	116	92	90	72	103	119	94	74	105	101	120	111	77	85	88	98	91	62	50	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	87	104	105	85	83	135	90	123	76	118	120	116	108	102	104	117	121	96	80	58	42	.....	.....
Fir, alpine (Colorado):																													
Green	4	.....	.....	110	85	137	97	102	109	110	104	87	97	105	110	67	108	97	100	154	125	100	117	107	112	121	108	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	103	111	91	184	81	128	71	96	71	106	123	111	95	125	96	90	122	102	113	101	90	.....	.....
Fir, amabilis (Oregon):																													
Green	39	.....	.....	.....	.....	.....	130	118	138	.....	.....	.....	.....	.....	.....	.....	150	115	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fir, amabilis (Washington):																													
Green	18	.....	.....	140	135	168	122	110	139	130	108	106	122	143	118	121	130	110	153	108	104	94	108	105	98	98	94	76	104
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fir, balsam (Wisconsin):																													
Green	14	.....	.....	105	88	116	112	102	113	129	96	76	112	114	132	99	129	104	132	81	87	94	104	99	94	96	90	74	71
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE 1.—*Equations and variations—specific gravity, shrinkage, and strength relations based on tests of small clear pieces, green and air-dry*—Con.

Species and locality.	Reference number.	Specific gravity, oven-dry, based on volume at time of test.	Moisture content.	Shrinkage from green to oven-dry condition.			Static bending.						Impact bending, 50-pound hammer.				Compression parallel to grain.			Compression perpendicular to grain, fiber stress at elastic limit.	Hardness: load required to embed a 0.444-inch ball one-half its diameter.			Shear.		Cleavage.		Tension.	
				In volume.	Radial.	Tangential.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Work to elastic limit.	Work to maximum load.	Total work.	Fiber stress at elastic limit.	Modulus of elasticity.	Work to elastic limit.	Height of drop causing complete failure.	Fiber stress at elastic limit.	Maximum crushing strength.	Modulus of elasticity.		End surface.	Radial surface.	Tangential surface.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.
			Per cent.	Per cent of dimensions when green.			Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inches.	Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.
III.—ACTUAL VALUE OF EACH PROPERTY FOR EACH "SPECIES-LOCALITY" AS DETERMINED BY TESTS—EXPRESSED IN PERCENTAGE OF EQUATION VALUE—Continued.																													
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
CONIFERS—contd.																													
Fir, grand (Montana):																													
Green	36	.....	.....	101	98	107	110	106	133	104	94	120	120	126	127	139	125	117	168	100	106	95	104	111	105	103	85	90	74
Air-dry	.....	.....	.....	.....	.....	.....	108	104	146	96	142	323	145	130	196	196	160	101	.....	79	113	98	142	101	97	328	66	45	52
Fir, noble (Oregon):																													
Green	16	.....	.....	137	147	153	119	111	143	117	112	135	120	128	135	111	130	112	171	111	85	76	83	105	101	76	76	63	71
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fir, white (California):																													
Green	17	.....	.....	93	102	118	135	116	125	169	94	123	114	126	121	106	144	116	132	146	106	100	105	118	106	106	119	91	108
Air-dry	.....	.....	.....	.....	.....	.....	119	108	127	137	92	113	82	93	92	91	130	115	129	118	150	121	119	95	109	106	104	72	90

Hemlock, black (Montana):																												
Green	47	.....	.....	90	110	100	99	95	88	123	123	172	106	93	128	139	114	100	101	94	110	99	100	106	99	87	92	83	101
Air-dry	.....	.....	.....	.....	.....	.....	101	92	84	140	105	77	117	104	146	154	105	103	97	135	139	97	102	90	95	66	64	49	88
Hemlock eastern (Tennessee):																												
Green	52	.....	.....	94	94	108	137	118	123	156	88	114	114	113	121	92	142	129	124	133	102	98	96	121	98	76	67	51	58
Air-dry	.....	.....	.....	.....	.....	.....	123	101	110	151	78	116	125	114	154	149	163	115	145	149	95	83	80	85	86	30	48	.....	29
Hemlock, eastern (Wisconsin):																												
Green	15	.....	.....	92	71	87	121	114	103	166	125	110	101	100	123	102	120	117	109	164	140	121	114	128	122	126	79	119	118
Air-dry	.....	.....	.....	.....	.....	.....	101	97	97	142	98	156	84	85	110	92	115	115	105	121	146	103	86	118	118	88	67	83	.....
Hemlock, western (Washington):																												
Green	50	.....	.....	.....	.....	.....	126	116	135	.....	.....	.....	.....	.....	.....	.....	147	117	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	93	110	126	.....	.....	.....	.....	.....	.....	.....	.....	102	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Larch, western (Montana):																												
Green	84	.....	.....	93	89	96	112	98	109	113	66	64	93	108	96	67	115	113	107	90	61	66	67	91	83	53	52	40	45
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Larch, western (Washington):																												
Green	64	.....	.....	.....	.....	.....	110	104	114	.....	.....	.....	.....	.....	.....	.....	.....	117	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pine, Cuban (Florida):																												
Green	127	.....	.....	76	106	76	106	92	110	90	54	72	92	105	74	76	115	111	108	71	53	65	64	86	71	46	44	40	40
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pine, jack (Wisconsin):																												
Green	43	.....	.....	90	90	97	92	93	92	98	87	128	103	90	108	132	106	95	93	101	81	85	90	101	91	98	82	85	94
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pine, Jeffrey (California):																												
Green	33	.....	.....	93	124	107	103	90	102	117	76	110	103	100	123	107	104	93	106	113	77	90	98	97	96	87	94	83	90
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pine, loblolly (Florida):																												
Green	88	.....	.....	87	114	88	105	95	112	96	72	85	93	105	79	88	100	106	105	89	50	62	66	92	75	62	58	52	50
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pine, lodgepole (Colorado):																												
Green	31	.....	.....	110	119	113	106	99	112	117	91	61	97	100	109	79	118	99	115	117	69	84	86	96	98	87	76	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	129	109	113	188	121	105	69	88	66	86	143	108	101	130	86	95	112	95	80	98	72	.....	.....
Pine, lodgepole (Gallatin County, Montana):																												
Green	35a	.....	.....	115	130	108	100	102	122	93	85	112	108	116	117	125	98	104	135	95	74	86	93	99	90	81	72	69	64
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE 1.—*Equations and variations—specific gravity, shrinkage, and strength relations based on tests of small clear pieces, green and air-dry*—Con.

Species and locality.	Reference number.	Specific gravity, oven-dry, based on volume at time of test.	Moisture content.	Shrinkage from green to oven-dry condition.			Static bending.						Impact bending, 50-pound hammer.				Compression parallel to grain.			Compression perpendicular to grain, fiber stress at elastic limit.	Hardness: load required to embed a 0.444-inch ball one-half its diameter.			Shear.		Cleavage.		Tension.	
				In volume.	Radial.	Tangential.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Work to elastic limit.	Work to maximum load.	Total work.	Fiber stress at elastic limit.	Modulus of elasticity.	Work to elastic limit.	Height of drop causing complete failure.	Fiber stress at elastic limit.	Maximum crushing strength.	Modulus of elasticity.		End surface.	Radial surface.	Tangential surface.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.
			Per cent.	Per cent of dimensions when green.			Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inches.	Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.

III.—ACTUAL VALUE OF EACH PROPERTY FOR EACH "SPECIES-LOCALITY" AS DETERMINED BY TESTS—EXPRESSED IN PERCENTAGE OF EQUATION VALUE—Continued.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
CONIFERS—contd.																													
Pine, lodgepole (Granite County, Montana).																													
Green	41a	.....	.....	105	133	98	94	95	105	90	85	66	100	112	102	101	98	96	140	79	74	85	85	90	85	79	67	68	68
Air-dry																													
Pine, lodgepole (Jefferson County, Montana):																													
Green	40a	.....	.....	105	135	105	94	96	112	85	88	86	97	112	96	95	108	103	165	77	74	76	90	90	80	79	66	72	65
Air-dry																													

Pine, lodgepole (Wyoming):																													
Green	34	.....	.....	99	102	94	89	93	101	87	85	85	94	100	101	83	98	94	94	106	71	81	81	105	98	166	114	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	110	113	100	154	86	74	95	100	106	110	128	114	99	126	89	98	97	86	67	86	52	.....	.....
Pine, longleaf (Florida):																													
Green	123	.....	.....	74	93	71	104	92	112	87	54	72	91	109	68	67	113	110	111	73	50	61	64	89	73	46	38	37	36
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pine, longleaf (Lake Charles, Louisiana):																													
Green	113	.....	.....	82	102	83	115	99	117	96	60	74	91	111	68	69	127	118	123	81	53	67	69	90	81	48	44	44	44
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pine, longleaf (Tangipahoa Parish, Louisiana):																													
Green	96	.....	.....	88	119	85	109	104	126	90	69	104	90	109	71	88	112	117	125	69	67	66	69	96	80	59	50	44	55
Air-dry	.....	.....	.....	.....	.....	.....	105	107	117	94	95	96	94	110	85	96	111	121	109	92	66	73	80	113	89	77	45	61	52
Pine, longleaf (Mississippi):																													
Green	95	.....	.....	74	96	85	103	94	107	100	61	76	91	103	77	76	120	111	112	76	55	69	72	94	83	53	45	45	44
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pine, Norway (Wisconsin):																													
Green	57	.....	.....	92	110	96	99	95	123	83	68	128	86	107	72	100	102	101	131	76	58	65	64	93	78	72	60	46	44
Air-dry	.....	.....	.....	.....	.....	.....	119	117	123	128	106	110	106	115	106	96	128	126	129	77	76	81	90	98	76	81	67	77	95
Pine, pitch (Tennessee):																													
Green	71	.....	.....	87	107	93	86	88	91	88	83	114	94	87	94	86	80	94	88	90	73	85	88	97	88	80	73	80	61
Air-dry	.....	.....	.....	.....	.....	.....	86	85	90	93	72	65	102	96	138	83	93	91	103	169	81	94	88	92	88	86	72	64	100
Pine, pond (Florida):																													
Green	86	.....	.....	77	107	83	102	94	101	102	68	85	93	100	83	92	105	105	97	90	58	72	72	96	79	64	58	51	53
Air-dry	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pine, shortleaf (Arkansas):																													
Green	77	.....	.....	.....	.....	.....	107	105	117	95	.....	.....	.....	.....	.....	.....	133	108	.....	73	.....	.....	.....	78	65	.....	.....	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	.....	106	115	81	.....	.....	.....	.....	.....	.....	.....	103	.....	77	.....	.....	.....	80	70	.....	.....	.....	.....
Pine, sugar (California):																													
Green	22	.....	.....	85	85	92	113	100	106	140	88	92	101	100	119	92	124	105	100	121	90	94	105	106	99	112	110	94	100
Air-dry	.....	.....	.....	.....	.....	.....	112	106	106	139	87	84	100	101	125	112	150	112	119	107	110	108	102	125	90	119	119	106	121
Pine, Table Mountain (Tennessee):																													
Green	82	.....	.....	79	72	81	107	99	104	110	79	102	102	104	100	83	106	104	99	88	66	77	77	96	85	72	62	67	55
Air-dry	.....	.....	.....	.....	.....	.....	105	90	100	114	76	71	108	110	121	106	91	102	125	112	62	76	68	91	80	71	64	.....	.....
Pine, western white (Montana):																													
Green	42	.....	.....	104	109	111	106	96	132	94	74	117	100	118	96	104	131	113	141	88	74	81	86	94	87	90	84	68	76
Air-dry	.....	.....	.....	.....	.....	.....	126	106	136	144	149	146	119	138	121	139	150	114	153	110	77	96	88	.....	54	55	53	.....	34

TABLE 1.—*Equations and variations—specific gravity, shrinkage, and strength relations based on tests of small clear pieces, green and air-dry*—Con.

Species and locality.	Reference number.	Specific gravity, oven-dry, based on volume at time of test.	Moisture content.	Shrinkage from green to oven-dry condition.			Static bending.						Impact bending, 59-pound hammer.				Compression parallel to grain.			Compression perpendicular to grain, fiber stress at elastic limit.	Hardness: load required to embed a 0.444-inch ball one-half its diameter.			Shear.		Cleavage.		Tension.	
				In volume.	Radial.	Tangential.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Work to elastic limit.	Work to maximum load.	Total work.	Fiber stress at elastic limit.	Modulus of elasticity.	Work to elastic limit.	Height of drop causing complete failure.	Fiber stress at elastic limit.	Maximum crushing strength.	Modulus of elasticity.		End surface.	Radial surface.	Tangential surface.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.	Surface of failure radial.	Surface of failure tangential.
			Per cent.	Per cent of dimensions when green.			Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Inch lbs. per cu. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Inch lbs. per cu. in.	Inches.	Lbs. per sq. in.	Lbs. per sq. in.	1,000s of lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.	Lbs.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.
III.—ACTUAL VALUE OF EACH PROPERTY FOR EACH "SPECIES-LOCALITY" AS DETERMINED BY TESTS—EXPRESSED IN PERCENTAGE OF EQUATION VALUE—Continued.																													
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
CONIFERS—contd.																													
Pine, western yellow (Arizona):																													
Green	19	.....	.....	91	122	107	90	90	95	99	86	98	97	94	116	100	103	91	103	90	76	85	88	103	100	112	114	121	114
Air-dry	.....	.....	.....	.....	.....	.....	101	96	89	135	69	101	84	100	97	72	110	110	92	114	109	112	106	142	128	150	166	142	141
Pine, western (California):																													
Green	37	.....	.....	108	120	114	99	90	113	95	66	102	100	98	117	105	105	93	118	100	73	79	85	98	93	100	101	83	77
Air-dry	.....	.....	.....	.....	.....	.....	126	106	115	161	117	141	96	102	109	103	147	113	110	117	81	100	98	100	108	112	112	92	141
Pine, western (Colorado):																													
Green	41	.....	.....	90	102	87	100	92	104	104	86	73	91	100	90	88	107	97	105	119	71	83	85	92	88	84	74	.....	.....
Air-dry	.....	.....	.....	.....	.....	.....	95	111	99	110	99	110	75	97	73	109	125	110	87	102	92	94	87	98	93	121	103	.....	.....

Pine, western (Montana):																													
Green	32	....	....	87	99	94	98	92	93	121	88	110	92	93	106	93	105	93	100	90	72	83	88	95	89	105	96	94	101
Air-dry	....	....	....	....	....	....	113	90	109	142	90	125	109	111	139	100	129	103	127	111	85	96	101	97	86	94	93	110	86
Pine, white (Wisconsin):																													
Green	25	....	....	77	64	96	114	100	116	128	101	102	91	101	95	88	124	108	128	108	77	86	86	92	84	89	87	81	85
Air-dry	....	....	....	....	....	....	122	108	122	156	110	172	85	106	85	104	147	115	117	131	109	115	108	92	101	128	97	92	97
Redwood (Albion, California):																													
Green	28	....	....	....	....	....	107	143	120	....	....	....	....	....	....	....	....	165	....	202	....	....	....	....	....	....	....	....	....
Air-dry	....	....	....	....	....	....	86	101	96	....	....	....	....	....	....	....	143	114	92	118	....	....	....	79	73	....	....	....	....
Redwood (Korbel, California):																													
Green	13	....	....	....	....	....	171	140	122	....	....	....	....	....	....	....	....	166	....	213	....	....	....	....	....	....	....	....	....
Air-dry	....	....	....	....	....	....	96	113	114	....	....	....	....	....	....	....	103	124	115	98	....	....	....	86	56	....	....	....	....
Spruce, Engelmann (Grand County, Colorado):																													
Green	8	....	....	117	121	125	107	99	105	130	104	64	106	108	126	85	113	97	110	137	100	106	115	103	98	88	94	....	....
Air-dry	....	....	....	....	....	....	97	117	100	121	107	114	92	103	110	116	122	116	101	132	94	83	90	109	104	121	98	....	....
Spruce, Engelmann (San Miguel County, Colorado):																													
Green	3	....	....	123	107	121	94	93	106	112	128	86	89	91	104	96	106	87	113	142	100	105	110	91	93	102	98	....	....
Air-dry	....	....	....	....	....	....	86	138	105	92	139	182	71	85	74	85	95	112	97	108	92	104	110	75	72	110	98	....	....
Spruce, red (New Hampshire):	44																												
Green		....	....	....	....	....	108	102	117	116	92	....	....	....	....	....	....	107	....	96	83	83	87	103	99	77	85	....	....
Air-dry	....	....	....	....	....	....	107	122	125	106	128	149	96	109	100	144	....	121	....	77	94	95	103	103	104	85	81	....	....
Spruce, red (Tennessee):																													
Green	29	....	....	115	109	126	109	102	129	104	102	100	105	111	112	94	122	102	127	119	114	96	103	110	106	85	91	60	90
Air-dry	....	....	....	....	....	....	128	104	122	159	128	118	118	120	137	165	153	110	135	110	112	109	114	89	97	83	100	125	98
Spruce, white (New Hampshire):																													
Green	7	....	....	....	....	....	120	110	113	146	139	66	....	....	....	....	....	89	....	100	106	94	100	106	93	100	88	....	....
Air-dry	....	....	....	....	....	....	103	124	121	108	144	196	98	115	105	139	129	117	133	77	91	98	102	118	110	121	120	123	111
Spruce, white (Wisconsin):																													
Green	38	....	....	144	103	115	109	98	104	136	87	109	97	106	94	101	114	98	94	99	66	73	71	101	91	83	76	67	66
Air-dry	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Tamarack (Wisconsin):																													
Green	81	....	....	101	79	89	100	96	101	110	71	110	80	100	74	85	108	103	114	83	56	61	58	90	79	62	52	52	50
Air-dry	....	....	....	....	....	....	97	97	106	94	64	90	86	92	88	81	103	110	113	85	60	72	69	93	85	81	67	79	63
Yew, western (Washington):																													
Green	134	....	....	57	70	53	120	102	68	190	123	126	86	91	128	82	94	112	58	112	115	119	110	135	124	69	60	64	67
Air-dry	....	....	....	....	....	....	94	96	79	110	109	67	47	68	53	....	73	102	64	240	125	154	108	120	122	41	42	....	45

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 677

Contribution from the Bureau of Soils
MILTON WHITNEY, Chief

Washington, D. C. PROFESSIONAL PAPER. October 24, 1918

SOILS OF SOUTHERN NEW JERSEY AND THEIR USES.

By J. A. BONSTEEL, *Scientist in the Soil Survey.*

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CHARACTER OF THE REGION.

LOCATION.

The southern part of the State of New Jersey, lying south of the line of the Pennsylvania Railroad between Trenton and New Brunswick and comprising about 4,400 square miles, is a compact area within which the climatic conditions, the accessibility to great markets, the means of transportation to those markets, and the skill and industry of the agricultural population are sufficiently uniform to afford an unusual opportunity for the study of the influence of the character of the soil upon the production of farm crops.

This region lies between the Atlantic Ocean and the Delaware River and Bay. Its southern extremity is in latitude 38° 55′ N. and its northern border extends to latitude 40° 30′ N. It includes all of the counties of Monmouth, Ocean, Burlington, Camden, Atlantic, Gloucester, Salem, Cumberland, and Cape May, and the southeastern portions of Middlesex and Mercer.

The total land area of this region is 2,833,840 acres. The United State Census for 1910 shows that 1,311,244 acres are included in farms and that 880,755 acres are classed as improved farm lands.[1]

CLIMATE.

The climatic conditions which prevail in this region are summarized by the Weather Bureau in "Summary of Climatological Data, Section 99—The Southern Interior and Sea Coast of New Jersey." This summary shows that precipitation during the growing season is adequate for the production of normal crops and that the interval between killing frosts in spring and fall is normally sufficient to mature all of the general farm crops and the majority of the vegetables and fruits. The climatological tables also indicate that the conditions prevailing over the region are so uniform that no locality or section is especially favored over others. The more important climatic facts are summarized in the chart, figure 1. It would appear from this chart that, so far as climatic conditions are concerned, agriculture might be uniformly developed over the entire region.

MARKETS.

It will be seen from the chart, figure 2, that the entire region is favorably located with respect to the metropolitan district of New York, which, in 1910, possessed a total population of 6,630,559 and to the metropolitan district of Philadelphia, which possessed a population of 2,015,560 at that time. The extreme distance from the most remote point in southern New Jersey to New York City is a little less than 130 miles, and it is less than 75 miles to Philadelphia. Railroad communication is unusually well developed and a good system of highways tends to place all portions of the region in easy communication with the great market centers.

AGRICULTURAL POPULATION.

Southern New Jersey was originally settled about 275 years ago by agricultural peoples from the various countries of northern Europe. During the intervening period agriculture has been developed along lines suited to the broader local needs and to meet the specific requirements of the separate localities. Owing to the existence of great near-by markets agriculture has experienced a notable degree of specialization to meet market demands, and experience has generally developed the use to which the different soils of the region may best be put under the existing conditions of demand for farm products.

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[1] U. S. Census, 1910, vol. V, Agriculture, p. 740.

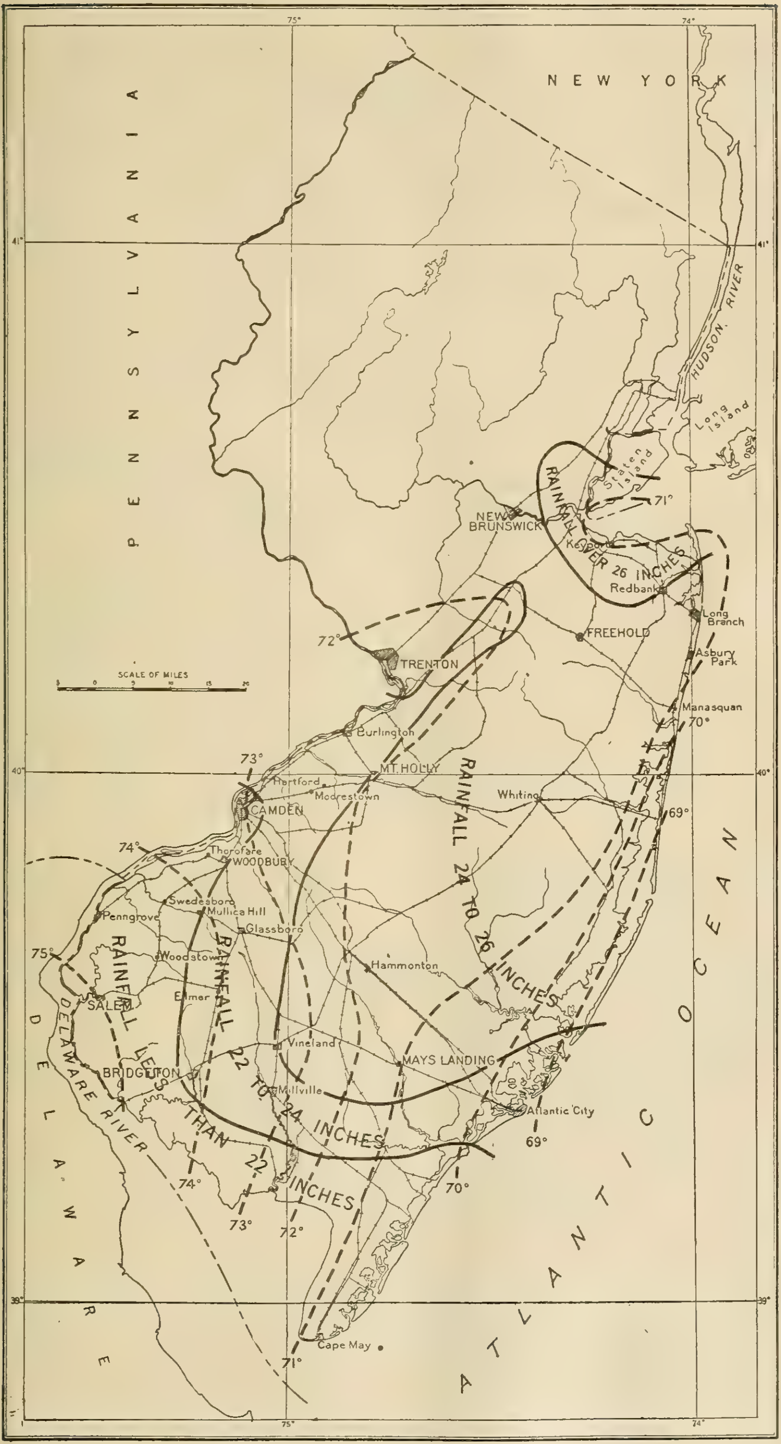

FIG. 1.—Rainfall zones and isotherms, summer season.

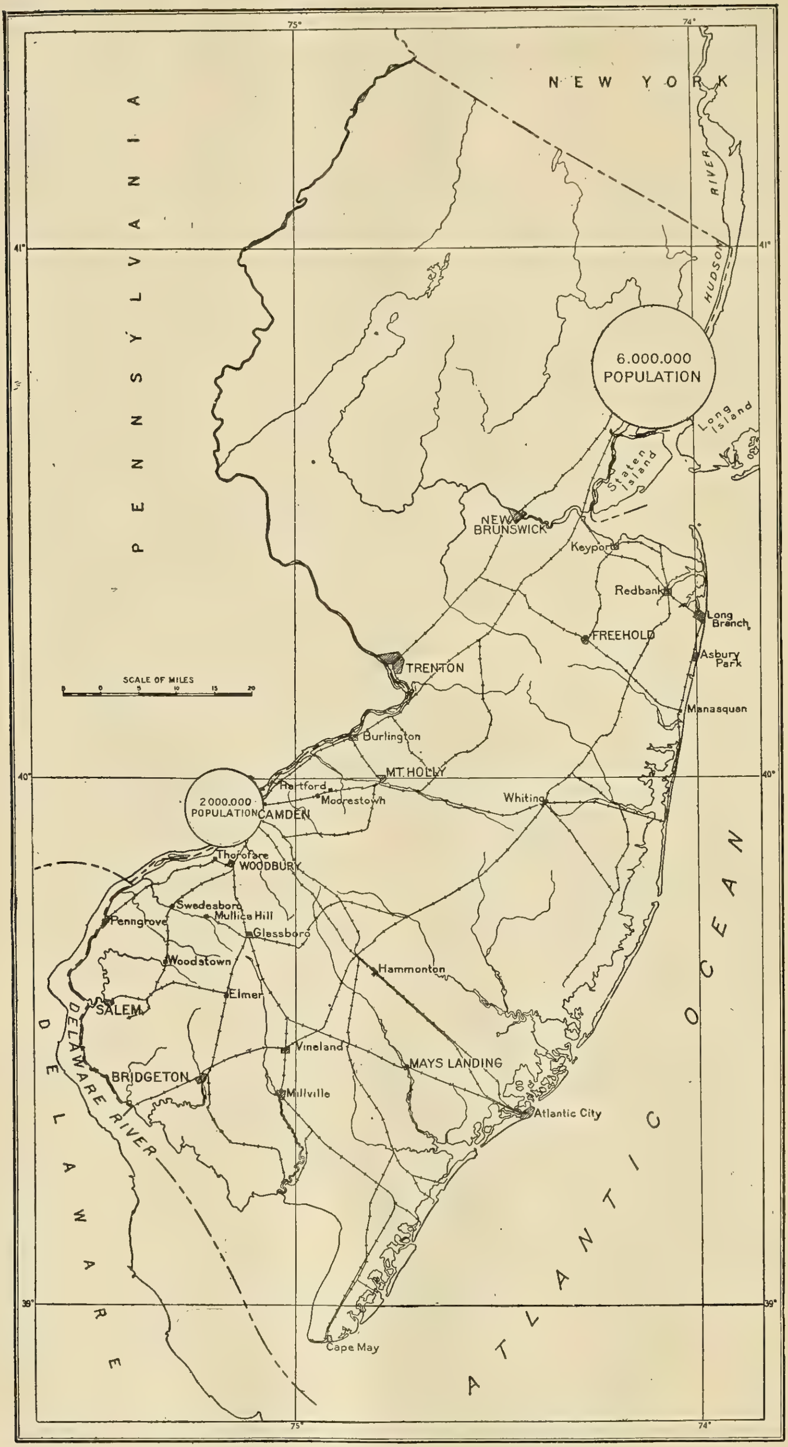

FIG. 2.—Chart showing metropolitan districts, principal towns, and connecting railroads.

PHYSICAL FEATURES.

The general surface features of southern New Jersey may be described as those of a gently sloping plain of low relief which is marked by a ridge extending from the Atlantic coast line near Sandy Hook to the vicinity of Delaware Bay, near Bridgeton, N. J. (See fig. 3, p. 6.) From this ridge the land surface slopes unequally toward the southeast and toward the northwest. The former slope frequently is at the rate of less than 5 feet to the mile, but the latter usually is greater and frequently is accomplished by steeper slopes intervening between areas which are gently sloping or nearly level. It is estimated by the New Jersey Geological Survey that less than 15 square miles of the section rise above an altitude of 200 feet and that not more than 120 square miles rise above 100 feet in elevation.

One of the marked features of the region is the presence along the shores of the Delaware River and Bay of a lowland or terrace of varying width which rises gently to an elevation of 40 to 50 feet. In places this lowland is not more than 2 or 3 miles broad, though in others it expands to a width of 10 or 12 miles. It is usually bounded, inland, by steeper slopes, rising to the watershed or to more elevated areas of gentle slope.

A very large proportion of the entire area is nearly level or but gently sloping, and it is only over restricted areas that the surface slope is too great or that the land is too broken to allow tillage.

SOILS.

Practically all of the soils of the region have been derived from unconsolidated sands, loams, clays, and marls. Only in scattered localities has there been any hardening of the material into cemented masses of sand and gravel, or, as they are locally known, "ironstone." Some gravel occurs throughout the region, either in beds underlying the soils or scattered in varying amount through the soil and subsoil.

There is a sufficient variety in the soil-forming material to give rise to a number of distinct soil types and series. These have been mapped and described in the soil surveys which have been made in the region, and a detailed account can be found in the different reports.[1] Therefore only a brief summary of the different soil series will be given.

Lakewood series.—The surface soils of the types in the Lakewood series are white in color and the subsoils orange yellow. The series occupies rolling to nearly level uplands in the Atlantic slope and

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[1] Field Operations of the Bureau of Soils, 1901, Soil Survey of the Salem Area, N. J.; idem, 1902, Soil Survey of the Trenton Area, N. J.; idem, 1913, Soil Survey of the Freehold Area, N. J.; and idem, 1915, Soil Survey of the Camden Area, N. J.

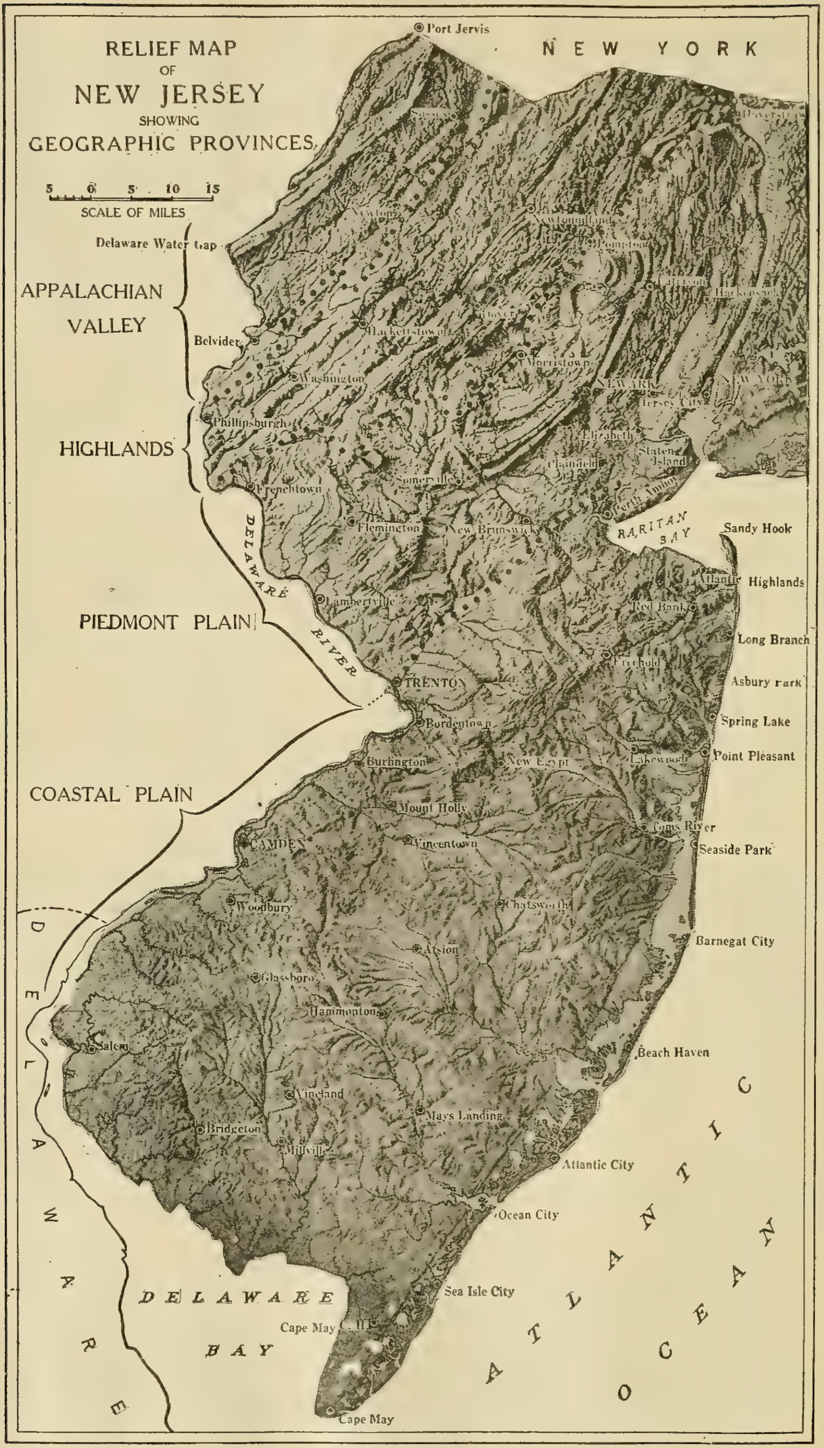

FIG. 3.—Geographic Provinces of New Jersey.

drainage is in many places excessive. The Lakewood sand, fine sand, and gravelly sandy loam have been mapped. The soils of this series are cultivated to only a small extent.

Sassafras series.—The surface soils of the Sassafras series are distinguished by a brown or yellowish-brown color and the subsoils are a deep yellow or reddish yellow. In many places a distinct bed of gravel or of coarse sand and gravel underlies these soils at a depth ranging from 2½ to 5 feet below the surface. The series is found in all parts of southern New Jersey, in somewhat scattered occurrences in the Atlantic slope, but especially well developed along the Delaware River and in the plain which extends between Trenton and New Brunswick. Most of the types in this series are well drained. The types of the series include the Sassafras coarse sand, sand, loamy sand, fine sand, gravelly sandy loam, coarse sandy loam, sandy loam, fine sandy loam, and loam.

Collington series.—The surface soils of the Collington series usually have a rather dark brown color and the subsoils are of a yellowish to greenish brown. The series is marked by the presence of glauconite or greensand in the subsoils. It occurs chiefly along a narrow belt extending southwestward from the vicinity of Atlantic Highlands nearly to Salem. This belt varies from 1 or 2 to nearly 15 miles in width. It is not entirely occupied by soils of the Collington series. The surface features of the soils of this series are varied, ranging from gently sloping or nearly level to distinctly hilly and broken. Probably 60 per cent of the area of these soils is sufficiently level to meet the requirements of cultivation. Drainage is well established over the greater part of the soils of the series, being defective only in the case of the heavier soils. The series includes the Collington sand, loamy sand, sandy loam, fine sandy loam, gravelly loam, loam, clay loam, and clay. The sandy loam and fine sandy loam are most extensive and of greatest importance agriculturally.

Colts Neck series.—The soils of the Colts Neck series are characterized by the brownish-red to dark-red color of the surface soils and by the bright to deep red color of the subsoils. They occur typically in the hilly to undulating areas of the marl belt and are well drained and easily tilled where the surface slope is not too great. The series includes the Colts Neck gravelly sand, loamy sand, sandy loam, fine sandy loam, and loam.

Norfolk series.—The soils of this series are marked by the grayish color of the surface soils and by the yellow color and friable structure of the subsoils. Only the Norfolk fine sand has thus far been encountered in southern New Jersey. It is usually hilly to rolling, well drained, and for the most part forested. Only the more level areas are occupied by farms.

Keyport series.—The surface soils of the Keyport series are grayish brown to brown in color and the subsoils are yellow and friable to mottled drab and yellow and somewhat plastic in the deeper subsoil. The surface soils are usually well drained, but artificial underdrainage is frequently needed on the heavier types. The soils of this series are of limited extent, occurring chiefly around Raritan Bay. The Keyport sandy loam, fine sandy loam, loam, and clay loam have been mapped.

Shrewsbury series.—The surface soils of the Shrewsbury series are gray to grayish brown in color and the subsoils are mottled gray, yellow, drab, and green. The series is chiefly found in low areas and slight depressions, and the deeper subsoils usually contain an appreciable quantity of greensand. The Shrewsbury sandy loam, fine sandy loam, loam, and silt loam have been mapped.

Keansburg series.—The surface soils of the types in the Keansburg series are dark gray to black and well supplied with organic matter. The subsoils are mottled gray, drab, and yellow and marked with reddish iron stains. The presence of greensand can sometimes be distinguished. The soils of this series occupy depressed, poorly drained areas in the marl belt and require artificial drainage to become of agricultural value. The Keansburg sand, sandy loam, fine sandy loam, and loam have been mapped.

Elkton series.—The surface soils of the Elkton series are ashy gray to brownish gray in color, and the subsoils are pale yellow, becoming mottled yellow and gray at lower depths. They are usually associated with soils of the Sassafras series, occupying flat or depressed areas where drainage is imperfect. Only the Elkton loam has been mapped.

Portsmouth series.—The surface soils of the Portsmouth series are dark gray to black in color and well supplied with organic matter. The subsoils are pale gray to nearly white, sometimes faintly mottled with yellow. These soils occupy depressed and poorly drained areas, chiefly along streamways and around the headwaters of swampy streams. They are chiefly forested and require artificial drainage before they are available for agricultural use. The Portsmouth sandy loam and loam have been mapped in southern New Jersey.

Hyde series.—The soils of the Hyde series are characterized by their naturally poor drainage and by the black color of both soil and subsoil to a depth of 3 feet or more. They are high in organic matter. They occupy low-lying and depressed areas along streams, around stream heads, and in swampy upland positions. They must be artificially drained before they can be cropped. Only the Hyde loamy sand has been mapped in southern New Jersey.

Freneau series.—The surface soils of the types included in the Freneau series are dark brown or mottled brown and reddish brown in color. The subsoils are mottled reddish brown, green, and drab. The Freneau loam is the only type of the series mapped in southern New Jersey. It occupies stream bottoms within the marl belt, and is naturally poorly drained. It is chiefly forested or used for pasturage, although small areas have been drained and cultivated.

Tidal marsh.—Considerable areas of Tidal marsh occur around the coast line of southern New Jersey. Some areas have been diked and drained and are used for pasture, the cutting of hay, and, to a small extent, the growing of corn.

Meadow.—Immediately inland from the Tidal marsh areas the streams of southern New Jersey are frequently bordered by nearly level, marshy tracts which are subject to occasional inundation by stream freshets and to the addition of new soil material. These flood-plain areas have been mapped as Meadow. They are either forested or used for grazing.

Coastal beach.—Between the tidal marshes and the ocean or bay there are sandy accumulations in the form of barrier beaches which have been mapped as Coastal beach. Owing to the sandy nature and uneven surface, together with the shifting of the surface materials under wind action, these areas have no agricultural value.

GENERAL VIEW OF THE SOIL-CROP RELATIONS OF SOUTHERN NEW JERSEY.

There are three rather distinct subdivisions of the region into a forested area, occurring chiefly within the Atlantic slope, a tide marsh area, which intervenes between the barrier beaches along the Atlantic Ocean and the main land and which also fringes the lower reaches of the Delaware River and Bay, and a long, narrow, curved belt of dominantly agricultural lands, which stretches from the waters of Raritan Bay southwestward to the Delaware River and thence borders that river and Delaware Bay to the mouth of the Maurice River.

These three regions of differing occupation correspond closely with the major soil differences of the region. The forested area is clearly related to the prevailing areas of the white sandy soils of the Lakewood series (fig. 4). These soils are normally too porous to retain sufficient moisture for the production of either staple or special crops. Experience has shown that the territory had best remain in timber. The tide marsh areas (fig. 5), on the other hand, are too wet under normal conditions to permit of crop production and it is only in restricted areas, where diking and drainage have been installed, that these areas are used to produce crops of any kind. Where they have been reclaimed, crops of hay (fig. 6) and corn are grown, although a considerable portion of such areas is only used for grazing. These subdivisions are excluded from present agricultural utilization by the two extremes of soil drainage. One is prevailingly too dry, the other too wet.

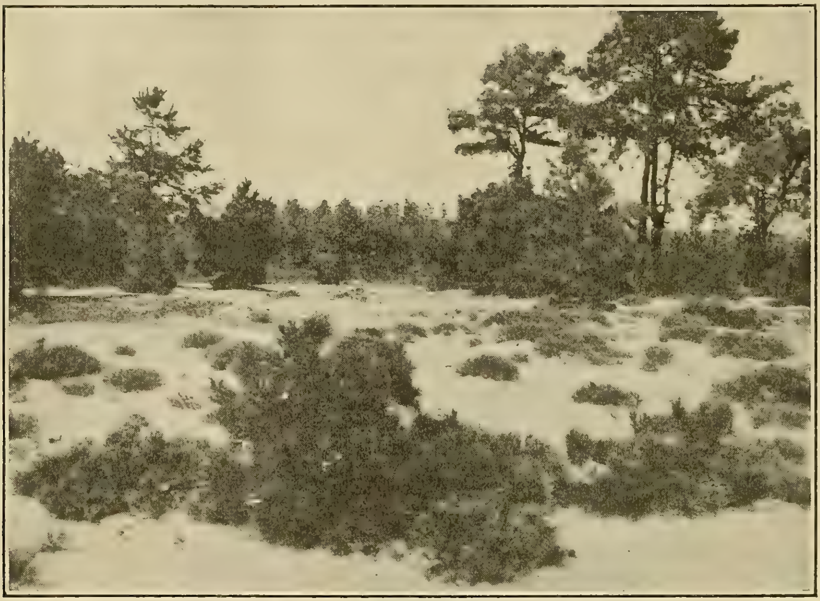

FIG. 4.—Pitch pine and scrub oak on the Lakewood sand.

FIG. 5.—Unreclaimed Tide marsh along Delaware River.

The third division of the region includes all of those soils of intermediate drainage conditions which may be occupied more or less intensively for some form of crop production. Within that division agriculture has been developed to a high degree of specialization, with a certain amount of selection of particular soil conditions for the growing of specific crops. Probably the two most important natural factors determining the class of occupation of the land in this region are the topographic features of land slope and the natural drainage conditions of the upland soil types.

Since the surface slope largely controls the mechanical efficiency of farming operations, rough, sloping land may not be economically occupied for the purposes even of staple crop production. Yet where slopes are not too steep or the surface too broken the excellent facilities for both air and soil drainage frequently render such situations desirable for certain forms of orcharding. In eastern Monmouth County such areas occur with soil conditions otherwise favorable to agriculture. Some of the finest orchards in the region are located on these rolling to decidedly hilly lands. In other cases where the land is too broken or danger from destructive erosion is too great, the land is either in forest or occupied as pastures.

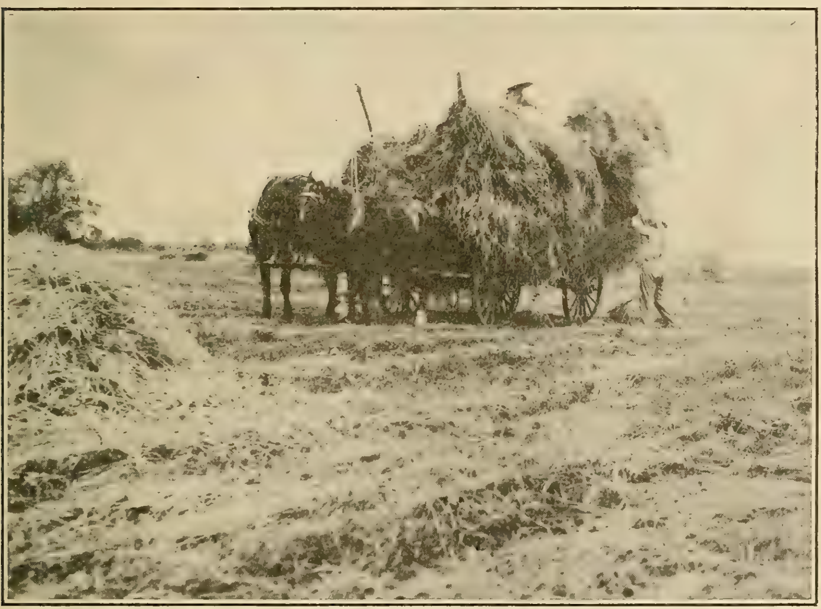

FIG. 6.—Harvesting timothy hay on reclaimed Tide marsh, near Woodbury, N. J.

A second class of lands within the dominant agricultural region which has escaped the intensive occupation common to the region comprises such soils as from their position or texture are commonly waterlogged.

Along many of the minor drainage ways the sluggish stream course is bordered on one or both sides by lands subject to periodical overflow. Such areas are quite commonly grown up to water-loving trees, shrubs, and vines, and their only present use is to furnish scanty pasturage. In some cases the broader bottoms have been cleared, and excellent pasturage is found on the moist bottom soils. Some of the larger areas have been ditched and even tile drained and are used for growing forage crops, potatoes, and cabbage. Small areas of this class of land, commonly mapped on the soil maps as Meadow, are highly esteemed, if not present in too great area, because of the pasturage afforded to work stock used on the intensively farmed upland or to small herds of dairy cattle.

There are also considerable areas of soils which in their natural condition require artificial drainage to become suited to the growing of the staple and special crops common to the region. Such soils in southern New Jersey fall chiefly into the Freneau, Hyde, Portsmouth, and Elkton series. The greater part of the total area of these soils in the section is either forested or used for pasturage or for the cutting of hay.

Usually soils of these classes are first cleared to afford added areas of pasture and, later, to come under cultivation for growing the forage crops required on the particular farm. Sometimes small bodies of any of these soils, which extend into larger areas of upland soils, may be drained more completely either by open ditches or by tile, and utilized along with the remainder of the individual field for the growing of the staple or special crops. In such cases the common crops of the section are extended over such small areas without any particular reference to natural soil boundaries.

The soils of the Keansburg, Shrewsbury, and Keyport series are rather better drained than the preceding group, but usually require some attention to artificial drainage before they are available for extensive agricultural use. Even in their natural state they may be used to produce grass and hay, and a considerable proportion of their total area will support good crops of corn. For more intensive forms of farming, however, they frequently require ditching and tiling. When this is done they give good returns with such crops as potatoes and cabbage. The heavier soils of these series are commonly used for forage crops, while the more sandy types are somewhat preferred for the growing of the later and heavier truck crops.

The general reconnoissance of the entire territory of southern New Jersey soon showed that the chief agricultural development, and especially the extension of the more intensive forms of cropping, had occurred upon soils of the Sassafras, Collington, and Colts Neck series. With these soils must also be included the small areas of soils of the Norfolk series to be found in the section. Not only are the soils of these series the unquestioned basis for the greater part of the agriculture of the region, but even scattered and restricted areas of these types when distributed among broader areas of less desirable types have been sought out and cleared. Such areas are found in many of the smaller clearings which are interspersed through the forested area, and they constitute an excellent illustration of the influence exerted by the character of the soil upon the agricultural occupation.

It is not by chance that the intensive forms of truck and fruit growing and the more extensive forms of staple cropping have been developed upon these particular soils. Years of experience have taught that soils of these groups constitute the safe foundation for agriculture and that they excel all other soils of the region for staple and special crop production.

A comparison of the map showing the general distribution of soil groups with that showing the tilled and forested land in southern New Jersey will at once demonstrate this selective use of the soils of the region.

The specialization of agricultural development within southern New Jersey has not rested merely with the occupation of certain general soil groups for farming purposes while others have remained uncultivated.

Among these chosen agricultural soils, experience has shown that certain soils are most successfully used for certain crops and successions of crops, and there has arisen a segregation of cropping practices which follows to a rather marked degree the specific characteristics of soils.

One of the best examples of this selection of soils for specific uses over a considerable territory may be observed in Salem County, N. J., and in adjacent portions of Cumberland County.

To the north and east of Salem and extending nearly to Elmer, quite to Shiloh, and almost to Bridgeton, N. J., is a large area of heavy loam soil, locally termed a "clay" in some cases. This large area of the Sassafras loam has long been the location of an excellent system of general farming in which corn, wheat, and hay have occupied the most prominent positions. In connection with these crops dairying has been practiced. Yields of each of these crops decidedly in excess of the average yields of the State or of the section are obtained. Until recent years this form of agriculture was almost the only one followed. The demand for certain special crops has lately brought about some changes in the cropping system, introducing potato growing and the production of tomatoes for the canning factory. Both of these special crops are well suited to the land in question. Few attempts are made to produce early market tomatoes, and in the case of potatoes dependence is chiefly placed upon the size of the crop rather than upon early maturity. Thus, even with increased specialization in cropping, careful attention is paid to the natural capabilities of the soil of this section.

This large area of heavy loam soil is sharply contrasted with areas of more sandy land to the north and east, on which the type of agriculture adopted is in no less marked contrast. Upon the sandy soils early market tomatoes, sweet potatoes, asparagus, corn, and clover predominate. Upon the heavy loam corn, wheat, mixed grasses, and Irish potatoes occupy nearly all of the acreage. Yet the climatic surroundings are essentially the same, and so also is the accessibility to market of different portions of the two areas.

Thus, even among the most desirable soils of southern New Jersey, experience has proved that careful attention must be paid to the inherent properties of the soils of any locality in order that the most profitable kind of cropping and the best adjusted system of agriculture may survive upon them.

These observations markedly illustrate the fact that the character of the soil, other things being equal, determines not only the character of the crops which may be grown successfully and the class of farming which will result but also the fact that extreme differences in soil condition will determine the major fact as to whether soils may be occupied for agriculture at all.[1]

DETAILED SOIL AND CROP MAPS.

In order that an exact estimation might be made of the actual uses to which soils are put in southern New Jersey, several very detailed soil and crop surveys were made of selected areas within the territory.

One survey was made immediately south of Freehold, in a highly specialized potato-growing section. Another was made in the vicinity of Hartford, another around Thorofare, and a fourth immediately to the north of Swedesboro. All of these areas are located within an intensively farmed belt, and the four areas include within their limits some portions of all of the more important agricultural soils of the section. They are all well supplied with transportation facilities and all are readily accessible to markets capable of absorbing considerable quantities of all the products which may be grown under the existing climatic conditions.

It is safe to say, therefore, that existing differences in cropping are measurably capable of correlation with the differences in soil characteristics which are found to exist.

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[1] More detailed statements with respect to these major matters of the distinctive uses of soils for the growing of particular crops may be found in the various reports upon the areas of which soil surveys have already been made in southern New Jersey, a list of which is given in a footnote on page 5. A similar correlation of soil and crop facts has been made and published for a portion of the territory under discussion in Farmers' Bulletin 472, of the United States Department of Agriculture, "Systems of Farming in Central New Jersey," by Geo. A. Billings and J. C. Beavers.

Each of the four areas constitutes a portion of a locality which has been developed to a marked degree for special agricultural production. It is in such areas that the closest adjustments of farm practices to natural conditions may naturally be looked for. It may reasonably be held that the existing adaptations of crop to soil have resulted from the observations of skilled farmers acting through a considerable period of years. In all four areas the sums invested in each year's operations represent a risk which the individual farmer desires to minimize through the adoption of every proved device of agricultural art which will add certainty to his prospects of profit.

In all cases the field maps were platted upon a scale of 6 inches to the mile through the ordinary methods of plane-table survey. Boundaries of fields and of other forms of occupation are shown and the kind of crop occupying each area of land at the time of the survey is indicated. This cultural map is combined with a detailed soil map so that the relationship of crops to soil may be read directly from the single map.

In order that the details of soil occupation might be determined, the completed maps were measured and the acreage of each form of occupation of each soil type was computed.

The accuracy of all of the maps is controlled by adjustment to the topographic maps of the region, executed by the New Jersey Geological Survey in cooperation with the United States Geological Survey. Upon the scale adopted for this special soil and crop mapping it is estimated that accuracy may be attained down to the limit of one-fourth of an acre.

The total area of each map and of each soil type was measured, and the total area of each crop upon each soil type was also measured, independently. It was found that interplanting and duplication of cropping gave rise to an excess of land occupation over total land area in some instances. In all cases the percentages of land occupation are figured on the basis of the total land occupation, in order to give each soil type its full weight in the production of each crop.

Table I shows the relationship between total land areas and total occupation by crops and otherwise for each area mapped.

TABLE I.—*Total area, area occupied by crops, and area of waste land in each of the four soil-crop survey areas.*

Area.	Total area mapped.	Total area of intensive occupation.	Total area rough and swampy lands.
	Acres.	*Acres.*	*Acres.*
Freehold	2,515.8	2,507.1	....
Hartford	2,259.1	2,078.6	216.6
Thorofare	1,476.3	1,358.5	123.5
Swedesboro	2,597.3	2,490.9	144.4

SOIL AND CROP SURVEY OF THE FREEHOLD AREA.

The area immediately south of Freehold was studied and mapped during August, 1914. It is located upon the Amboy Division of the Pennsylvania Railroad and upon the Central Railroad of New Jersey about 40 miles from New York City, 30 miles from Trenton, N. J., and 70 miles from Philadelphia, Pa. Its location with respect to both markets and transportation, therefore, is favorable.

The area mapped is located just south of the ridge which divides the Atlantic drainage from that of the Delaware River. The highest elevation within the area of the map—190 feet above tide level—occurs within the limits of Freehold. There is a gentle slope to the south throughout the area and an altitude of 140 feet is reached along the southern border of the map.

The location of this detailed map is indicated on Plate A, page 16. The topography and soil conditions of the general region are shown on the large map of the Freehold area published to accompany the regular soil survey of that section.[1]

SOILS.

Freehold is located within what is known as the "marl belt" of southern New Jersey. As a result, the underlying materials within the limits of the map consist chiefly of glauconite, or greensand, containing variable proportions of clay and quartz sand. To a small extent the area is also underlain by the rusty, red, sticky sand of the Redbank formation, which contains plates and angular fragments of iron crust.

Over the greater part of the area this basal material is covered to varying depths by later deposits, and the deeper layers are chiefly exposed along the margins of streams upon rather steeply sloping areas.

The underlying marl beds have influenced the surface layers from which the dominant soils are derived to some degree and the deeper subsoils sometimes show unmistakable evidences of admixture of marl.

Sassafras loam.—The surface soil of the Sassafras loam, to an average depth of 10 or 12 inches, is a mellow, brown to dark-brown silty loam. It is underlain by a yellowish-brown to brown, heavy silty loam, which is rather more compact than the surface soil. The total depth of surface soil and subsoil in the Freehold area ranges from 1 or 2 feet along the slopes to the streams to 5 or 6 feet over the greater part of the upland.

In the Freehold area, as elsewhere in southern New Jersey, the type occupies nearly level to gently sloping uplands, and natural drainage is well established over the greater part of its surface.

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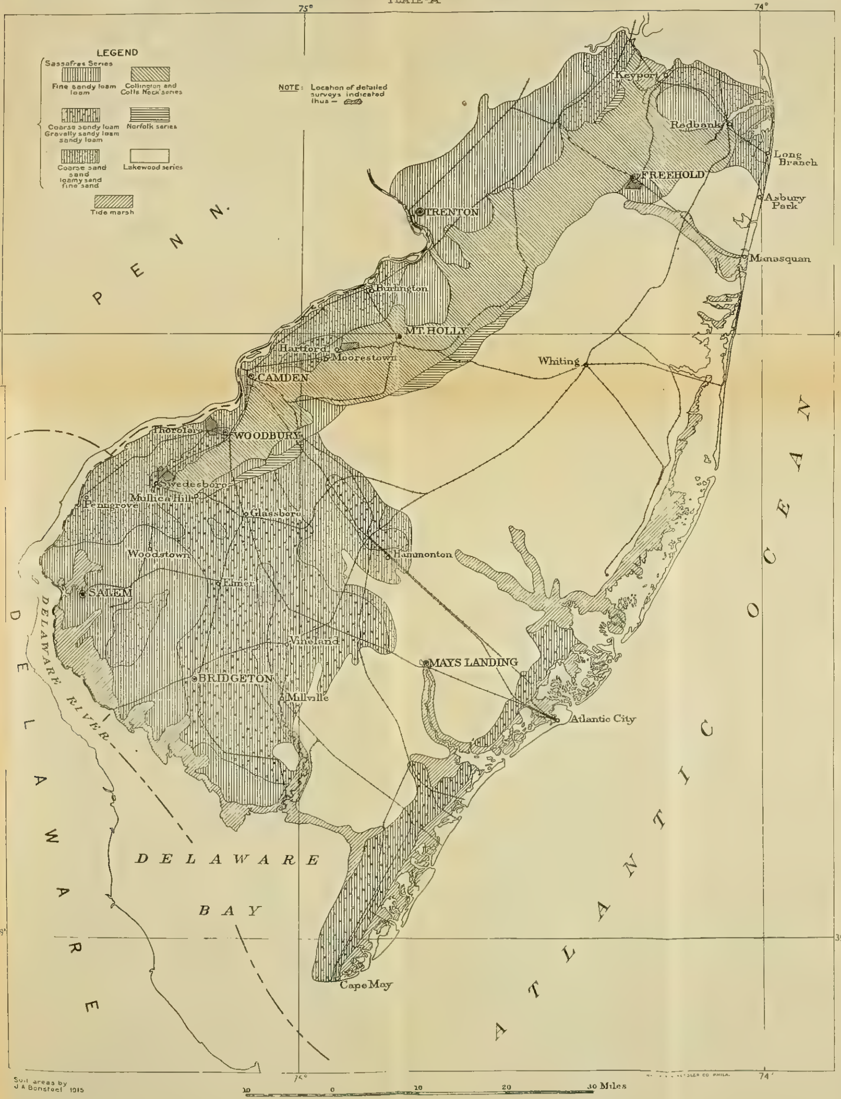
[1] Field Operations of the Bureau of Soils, 1913, p. 95.

U. S. DEPT. OF AGRICULTURE
BUREAU OF SOILS
MILTON WHITNEY, CHIEF
CURTIS F. MARBUT, IN CHARGE SOIL SURVEY

GENERALIZED SOIL MAP

PLATE-A

SOUTHERN NEW JERSEY



Soil areas by J. A. Bonsteel 1915

Bulletin 677, U. S. Department of Agriculture

This soil is representative of considerable tracts of land mapped as the Sassafras loam in the detailed surveys of the Camden, Freehold, Trenton, and Salem areas. It contains a slightly greater amount of greensand or glauconite in the deeper portions of the subsoil than is common, but in all other respects is typical.

It is recognized as a strong, productive agricultural soil best suited to the growing of general farm crops and of Irish potatoes. Practically every acre of the type is cleared and occupied for agricultural purposes both in the Freehold area and elsewhere in southern New Jersey.

Sassafras sandy loam.—The surface soil of the Sassafras sandy loam to an average depth of 8 to 10 inches consists of a light yellowish brown to brown sandy loam. It is somewhat heavy and coherent where it is associated with the Sassafras loam in the vicinity of Freehold. The subsoil is a yellow or yellowish-brown heavy sandy loam, which grades at a depth of about 30 inches into a more porous loamy sand.

The type is chiefly found on gentle upland slopes in the vicinity of Freehold, and the greater part of its area is well drained.

Colts Neck loam.—The surface soil of the Colts Neck loam, to an average depth of 7 or 8 inches, is a distinctly red or dark-red loam. The subsoil, to a depth of 30 inches, is a sticky, coherent, red loam. Usually below 30 inches the subsoil is more porous and the color a rusty red. In the vicinity of Freehold broken fragments of iron-cemented sand are found in the subsoil.

The surface of the type within the limits of the detailed soil and crop map made near Freehold is nearly level to gently sloping and the type is well drained. It is found chiefly along the gentle slopes from the upland to the streamways which drain the area. It only occupies a few narrow areas, forming portions of fields, and it is consequently tilled to the same crops and in the same rotations as the more extensive Sassafras loam, with which it is associated.

It is commonly used for the growing of corn, wheat, and hay. Irish potatoes are also grown, although the staining of the tubers, through the adhesion of red particles of soil slightly decreases their market value.

Colts Neck sandy loam.—The surface soil of the Colts Neck sandy loam varies from a bright-red to a dark-red sandy loam. The subsoil is a distinctly red, light sandy loam which grades downward into a somewhat more coherent sandy loam or sandy clay.

The type is of small extent, occurring near Freehold, where it occupies long, narrow, sloping strips along streamways. The surface is decidedly sloping, and the narrow strips of the type are not tilled differently from other soils with which they are associated.

Collington loam.—The surface soil of the Collington loam, to a depth of nearly 8 inches, consists of a brown loam, generally having a slight olive green tinge. The typical subsoil is a greenish-yellow loam, which in some cases is rather heavy and coherent. A considerable amount of greensand or glauconite is found in both surface soil and subsoil, particularly in the latter. The type is derived through the weathering of the underlying marl beds.

The surface is generally level and the natural drainage has become well established. Only small areas of the type are found in the immediate vicinity of Freehold and no distinctive cropping system has been developed for this soil.

Collington clay loam.—The surface soil of the Collington clay loam is a dark-brown to almost black loam having a depth varying from 3 to 6 inches. The immediate subsoil is a dark-brown to dark-green compact clay loam or clay. The deeper subsoil is somewhat more granular, and grades into the greensand marl from which the type is derived. It occurs only in small areas where marl beds are exposed at the surface.

The surface of this soil type is level or gently sloping. Drainage is fairly well established. Owing to its small extent, both near Freehold and elsewhere in southern New Jersey, no distinctive cropping system has been developed for it, although it is commonly recognized as being better suited for the production of grass and grain than for any other crops.

Collington sandy loam.—The surface soil of the Collington sandy loam, to an average depth of about 9 inches, is a light-brown to brown sandy loam, frequently showing a distinct greenish tinge. The immediate subsoil is a greenish-yellow sandy loam which becomes heavier and more coherent with depth. At about 30 inches it grades into a green loam or sandy clay, representing the greensand marl from which the type is derived.

The type occurs only to a limited extent near Freehold along sloping stream banks and it is not distinctively farmed.

Freneau loam.—Narrow stretches of somewhat poorly drained bottom land along the shallow stream courses within the area were mapped as the Freneau loam. In many cases, near Freehold, open ditches have been dug through this type and drainage has been sufficiently established to permit of crop production. The greater part of the type is used for pasture or the cutting of hay. The surface soil varies from place to place, but the subsoil consists rather uniformly of unweathered greensand marl, dark green in color and decidedly sticky and wet.

The Sassafras loam occupies 87.6 per cent of the total area surveyed, and all other types mapped are not only subordinate in extent but also in importance. This type practically fixes the form of agriculture and the crop usages of the area represented.

The absolute and relative extent of the different soils mapped in the Freehold area is given in Table II.

TABLE II.—*Extent of different soil types, Freehold area.*

Soil type.	Area occupied.	Proportion of total occupied area.	Soil type.	Area occupied.	Proportion of total occupied area.
	Acres.	*Per cent.*		*Acres.*	*Per cent.*
Sassafras loam	2,098.8	83.7	Collington clay loam	15.3	0.6
Sassafras sandy loam	90.8	3.6	Collington sandy loam	14.1	.6
Colts Neck loam	68.2	2.7	Freneau loam	111.8	4.5
Colts Neck sandy loam	65.7	2.6			
Collington loam	42.4	1.7		2,507.1	....

These soil types comprise the upland farming area and aggregate 2,507.1 acres of land occupied either for the production of crops, as farm woodlot, or for the necessary sites of farm homesteads and farm lanes.

USES OF SOILS.

The interpretation of the agricultural uses of the soils of this area is based upon:

(1) The total acreage of each crop as it stood in August, 1914.

(2) The percentage relationship of each crop area to the total area of all farm crops as mapped.

(3) The classification of all crops recorded into general farm crops, including lima beans; truck crops, including Irish potatoes; fruit crops, including all orchard, berry, and nursery crops, and the supplementary areas of land not used for the production of any annual crop, but occupied by gardens and grounds, forested areas, and land not in crops for various reasons.

This classification gives an opportunity for the comparison of the crop uses of each type with the standard as established for the area by the percentages given for "all soils." For example, it will be seen that the percentage of the total area of the Sassafras loam which is given to potato growing is 42.4 per cent, while the percentage of all soils in the area is 40.3 per cent in potatoes. This indicates that the type is used somewhat more extensively for potato growing than the average, a matter to be expected, since a larger proportion of the type is under cultivation than the average for the area.

Table III summarizes this information:

TABLE III.—*Proportion of total area and of the area of each soil type occupied by various crops and groups of crops in the Freehold area.*

Crop group and crop.	All soils.		Sassafras loam.		Sassafras sandy loam.		Colts Neck loam.		Colts Neck sandy loam.		Collington loam.		Collington clay loam.		Collington sandy loam.		Freneau loam.	
	Acres.	*Per ct.*	*Acres.*	*Per ct.*	*Acres.*	*Per ct.*	*Acres.*	*Per ct.*	*Acres.*	*Per ct.*	*Acres.*	*Per ct.*	*Acres.*	*Per ct.*	*Acres.*	*Per ct.*	*Acres.*	*Per ct.*
General farm crops	1,272.4	50.7	1,026.1	48.8	47.6	52.3	52.4	76.8	47.0	71.5	9.4	22.1	4.1	26.8	10.9	77.3	74.9	66.9
Hay and pasture	676.6	27.0	511.1	24.3	26.1	28.7	37.6	55.1	22.9	34.7	6.8	16.0	1.2	7.8	2.4	17.0	68.5	60.9
Corn	330.0	13.1	296.3	14.1	9.6	10.6	6.4	9.4	3.2	4.9	1.6	3.8	2.9	19.0	7.8	55.3	2.2	2.0
Wheat	124.7	5.0	109.0	5.2	4.1	4.5	6.9	10.1	1.6	2.5	1.0	2.3					2.1	2.0
Lima beans	114.2	4.6	94.9	4.5					19.3	29.4								
Cowpeas	11.0	.4	6.0	.3	5.0	5.5												
Rye	9.9	.4	5.6	.3			1.5	2.2							.7	5.0	2.1	2.0
Beets (stock)	6.0	.2	3.2	.1	2.8	3.0												
Truck crops	1,010.1	40.3	889.8	42.4	39.2	43.1	12.2	18.0	13.1	20.0	32.0	75.5	5.6	36.6	3.2	22.7	15.0	13.4
Potatoes	996.1	39.7	879.4	41.9	39.2	43.1	12.2	18.0	13.1	20.0	31.2	73.6	2.8	18.3	3.2	22.7	15.0	13.4
Cucumbers	4.6	.2	4.6	.2														
Cabbage	4.0	.2	.7	.0							.5	1.2	2.8	18.3				
Cauliflower	3.2	.1	3.2	.2														
Beans	2.2	.1	1.4	.1							.3	.7						
Orchard and nursery	92.8	3.7	80.1	3.8	2.4	2.6			1.6	2.5	1.0	2.3	5.6	36.6			2.1	2.0
No annual crops	131.8	5.2	102.8	4.9	1.6	2.0	3.6	5.2	4.0	6.0							19.8	17.7
Garden and grounds	82.6	3.3	79.8	3.8	.8	1.0	1.5	2.2	.5	.8								
Forest	38.6	1.5	18.8	.9													19.8	17.7
No crop	10.6	.4	4.2	.2	.8	1.0	2.1	3.0	3.5	5.2								
Grand total	2,507.1	99.9	2,098.8	99.9	90.8	100.0	68.2	100.0	65.7	100.0	42.4	99.9	15.3	100.0	14.1	100.0	111.8	100.0

The character of the agriculture of the locality is easily seen from the table of crop occupation. Hay and pasture, corn, wheat, and potatoes occupy 85.5 per cent of the total land area. Adding to these crops the areas in fruit crops and those occupied by farmsteads, the total is 94.2 per cent of the area, leaving only 5.8 per cent of the area occupied by other crops, of which the largest single acreage is that of Lima beans. (Figure 7.) In fact, the other miscellaneous crops of the area cover only 1.2 per cent of its total acreage.

It is at once evident that the Sassafras loam, occupying 87.6 per cent of the total land area, dominates the cropping system. In fact, the area was selected for mapping because it gave an unusually good opportunity for the study of this type and its influence upon crop systems.

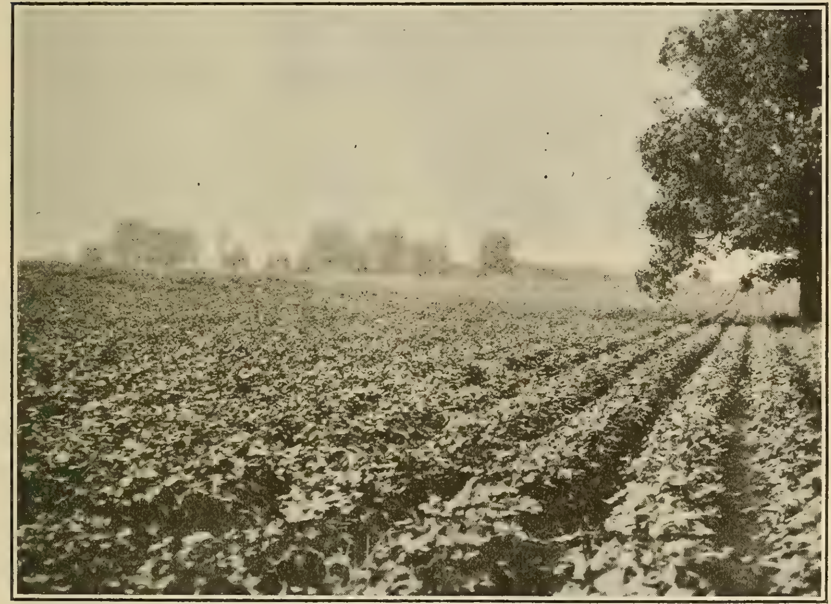


FIG. 7.—Bush Lima beans for canning, on Sassafras loam, near Freehold, N. J.

It was evident from a reconnoissance of southern New Jersey that the Sassafras loam was of leading importance in the production of corn, wheat, hay, and potatoes not only in Monmouth County but generally wherever it occurs in bodies of any size. Thus, in Mercer, Middlesex, Burlington, Camden, Gloucester, Salem, and Cumberland counties this soil is almost universally used over the greater part of its extent for the growing of these crops. Figures 8, 9, 10, 11, and 12 show the high state of cultivation and the productiveness of this soil when planted to these crops. In all localities where it is found in New Jersey it constitutes the standard soil type for this class of farming. In Monmouth County the specialization in potato growing has been pushed a little further than in many other localities, but the extension during the last 10 years of the area devoted to potato growing in southern New Jersey has been largely upon this soil.

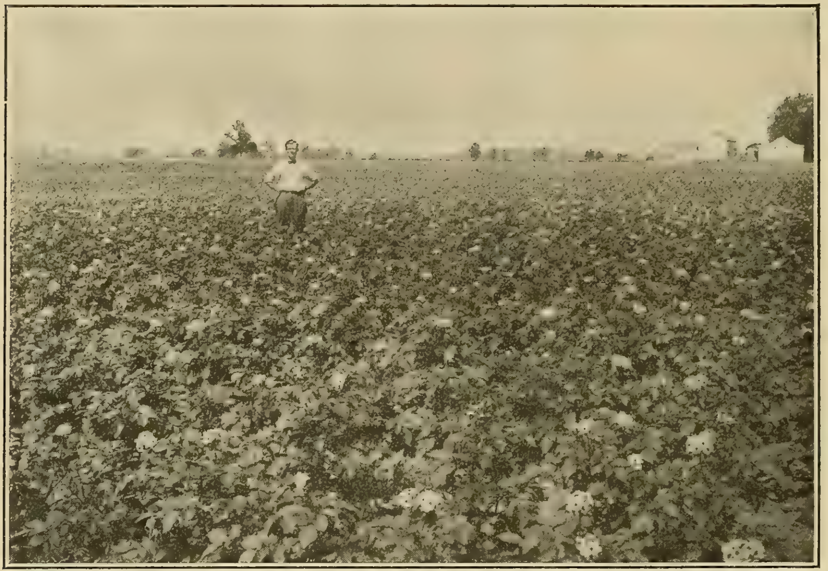


FIG. 8.—Field of American Giant potatoes on Sassafras loam, near Freehold, N. J. Yield over 275 bushels per acre.

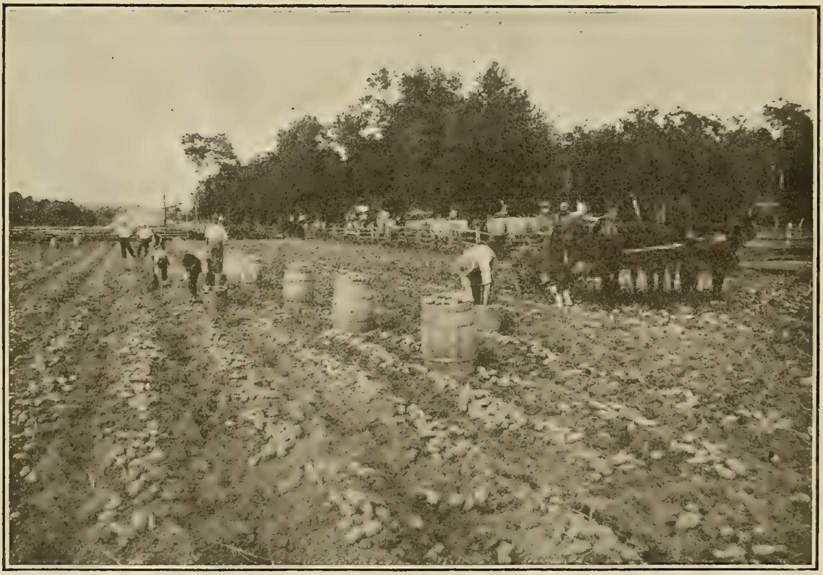


FIG. 9.—Digging and shipping American Giant potatoes, Sassafras loam, near Freehold, N. J. Yield over 275 bushels per acre.

A similar mapping of the crop areas upon the Sassafras loam, if made in the vicinity of Robbinsville, Mercer County, or near Woodstown, Elmer, or Salem, in Salem County, would show essentially the same facts of crop occupation, even if the absolute figures differed slightly from those here shown.

FIG. 10.—Red clover grown in rotation with corn, potatoes, and wheat on Sassafras loam, vicinity of Freehold, N. J. Yield 1½ to 2½ tons per acre.

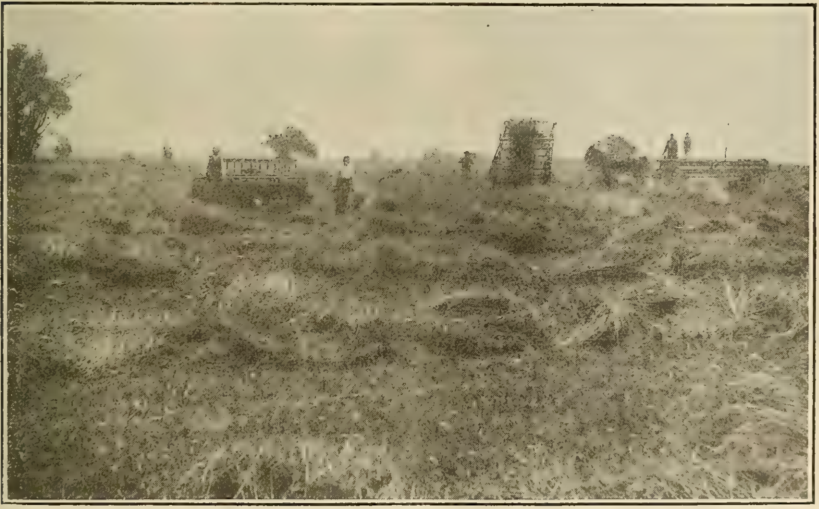


FIG. 11.—Timothy and clover hay grown on Sassafras loam, near Freehold, N. J. Yield, in rotation with corn, potatoes, and wheat, 1½ to 2 tons per acre.

Certain facts are worthy of particular notice in the study of the cropping uses made of the different soil types.

In the case of potatoes, 39.7 per cent of the entire Freehold area is given to that crop. Potatoes occupy 41.9 per cent of the cropped area of the Sassafras loam.

Hay is second in area to potatoes, occupying 27 per cent of the entire area, but covering only 24.3 per cent of the cropped area of the Sassafras loam.

Wheat is the only small-grain crop grown to any significant extent. It covers 5 per cent of the entire area, but occupies 5.2 per cent of the cropped area of the Sassafras loam.

These departures from the normal of all types indicate a tendency to use as large an area of the Sassafras loam as is compatible with good methods of farming for the growing of potatoes. Corn, wheat, and hay are grown in a regular rotation with potatoes, the succession and the duration of the crop occupation with each crop varying slightly with individual preferences. The strong tendency to keep the land in potatoes or corn is shown by the slight excess of the percentages in these crops on the Sassafras loam and the small deficiency of the percentage in hay compared with the standard figures for the area. In other words, this dominant and desirable soil type is kept in high-paying, cash crops for as much of the time as is possible in accordance with experience.

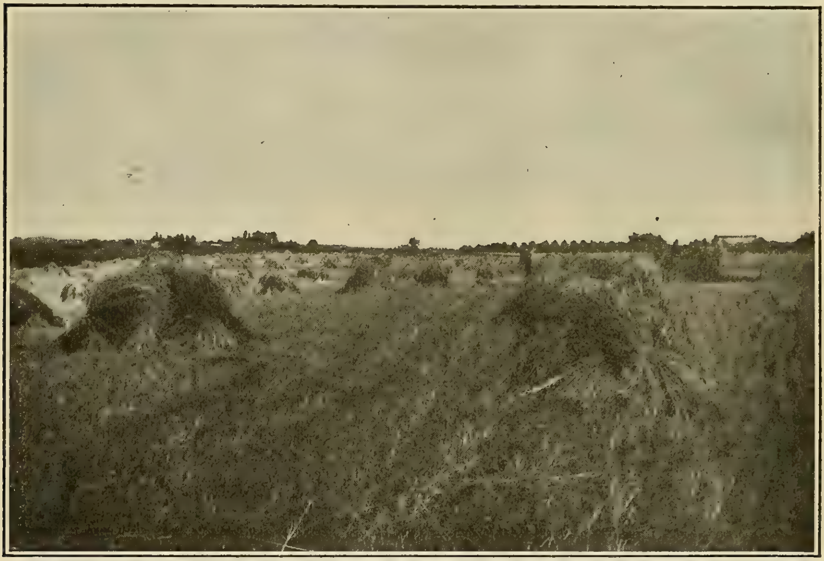


Fig. 12.—Winter wheat on Sassafras loam, near Freehold, N. J. Yield 25 bushels to 35 bushels per acre on land heavily fertilized for potatoes.

It should be stated that in central Monmouth County a special variety of Irish potato, the American Giant or "long stock," is grown. For this reason there is no opportunity to make any direct comparison of the local yields with those obtained in other localities where the Irish Cobbler or "round-stock" potato is chiefly grown. Other things being equal, the Giant will normally outyield the Cobbler by 20 to 25 per cent.

The relationship of the Sassafras loam to the production of Irish potatoes as a main money crop can not be too strongly emphasized in a consideration of the uses of the soils of southern New Jedsey. Thus the business of growing potatoes has been developed to a high degree of specialization in central Monmouth County. That this is due, at least to some degree, to the presence of large areas of the Sassafras loam is shown by the unusually large acreage borne by that soil type. The special adaptation of this soil to potato production is well known in the region and is specifically recorded by Jennings in the report on the Soil Survey of the Freehold Area, New Jersey. He says:

> The soils on which the principal crops of potatoes are grown have been classed as Sassafras loam, sandy loam, and fine sandy loam, and the Collington loam, sandy loam, and fine sandy loam. Other types are used to some extent, but the highest yields are secured on these soils, especially on the loam soils of the different series.

Jennings also makes the distinction in his report that the early crop of potatoes is grown to a considerable extent on the Sassafras fine sand, fine sandy loam, and sandy loam in conjunction with other truck crops. He states with regard to the Sassafras loam that "it is without exception the heaviest-yielding potato soil in the State."

The personal investigations of the author in 1914 and 1915 would indicate that this statement is generally true of the type wherever it is found in southern New Jersey. An examination of the soil survey maps of the Freehold, Trenton, Camden, and Salem areas will show that all of the most important potato-shipping localities in southern New Jersey are located on or in the immediate vicinity of extensive areas of the Sassafras loam. This is true of Holmdel, Freehold, Englishtown, Dayton, Hightstown, Mount Holly, Moorestown, Mullica Hill, Elmer, Woodstown, Salem, and Shiloh.

In the majority of these localities the potato crop, whether American Giant or Cobbler, is grown on the Sassafras loam with the Collington sandy loam second in importance and the Sassafras sandy loam and fine sandy loam contributing a large part of the remainder of the crop. Upon these four soil types considerably more than one-half of the total potato crop of the State is annually grown.[1]

SOIL AND CROP SURVEY OF HARTFORD AREA.

In order to study the relationship existing between soils and crops in an area of mixed general farming and special crop production in a favorable locality in southern New Jersey, a detailed map of the soils and the crops grown upon them was made in the vicinity of Hartford, Burlington County, N. J., in July and the early part of August, 1914.

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[1] For detailed statements with regard to the methods employed in potato growing in central New Jersey, the reader is referred to Farmers' Bulletin 472, of the U. S. Department of Agriculture, and to Bulletin 294, of the New Jersey Agricultural Experiment Station.

The Hartford area is located along the line of the Amboy Division of the Pennsylvania Railroad about 12 miles east of Camden. It is adjacent to Rancocas Creek and about 5 miles south of the Delaware River. The area mapped covers about 3¼ square miles, or 2,259.1 acres. It lies within the area of the soil survey of the Camden Area, N. J., completed in 1915.

The Hartford Area occupies a somewhat dissected portion of a relatively flat-topped terrace along the lower course of Rancocas Creek. The surface of the land rises from the level of the stream in a southwesterly direction to an altitude of 90 feet at a distance of nearly one-half mile from the creek. The area mapped is divided into an eastern and a western division by the deep-cut channel of Parkers Creek which flows across it between steep bounding walls, through a flat-bottomed, marshy valley.

The altitudes along the railroad, which forms the southern boundary of the area mapped, range from 40 to 50 feet above tide level, gently rising toward the center of the upland to an extreme elevation of 80 feet at a point about one-half mile north of Hartford and of 90 feet about three-fourths of a mile northwest of Masonville. Aside from the steeper slopes along the banks of Parkers Creek and toward Rancocas Creek, the surface of the area is rolling to gently undulating. Some minor streams have cut small valleys through the upland and their courses are in some cases bordered by narrow swampy flats. Generally the surface drainage of the area is well established. Small depressions in the surface of the upland might be improved by the installation of tile underdrainage.

SOILS.

The Hartford area lies within the marl belt of central New Jersey. All of the surface materials are underlain at varying depths by beds of marl ranging from a loose, marly sand to a rather stiff, black marl. The rolling upland is covered by more recent deposits forming a part of the more elevated terrace intermediate in altitude between the broad terrace which borders the Delaware and the uplands to the south. The terrace covering varies in thickness from 5 or 6 feet down to a thin veneer over the underlying marl formations. East of Parkers Creek the marl formations either reach the surface or are so thinly covered that they form the deeper subsoils and thus give character to the soils mapped in that section.

In consequence, the soils of the rolling upland in the western part of the area mapped consist chiefly of the Sassafras loam and sandy loam with associated areas of Elkton and Portsmouth types, while those of the eastern section include the Collington sand, sandy loam, and fine sandy loam.

Sassafras loam.—The Sassafras loam of the Hartford area does not differ materially from the same type as occurring in the Freehold area, except that there is possibly a smaller admixture of greensand marl in the deeper subsoil and the coloration of the subsoil is consequently a somewhat more reddish brown. The type occupies undulating to gently rolling uplands at elevations ranging from 50 to 90 feet above tide level and natural drainage is well established.

Sassafras sandy loam.—The Sassafras sandy loam differs slightly from the type as developed near Freehold, but is more nearly typical of the extensive areas found in other parts of southern New Jersey. The surface soil, near Hartford, to a depth of 10 or 12 inches, is a brown to dark-brown sandy loam. It is directly underlain by a pale-yellow sandy loam extending to a depth of 15 to 20 inches. This grades into reddish-yellow sandy clay. In the Hartford area a portion of the type occupying sloping ground contains an appreciable quantity of fine quartz gravel scattered through both soil and subsoil.

The surface of the type ranges from nearly level to decidedly sloping. Surface and internal drainage is well established.

Collington sand.—The surface soil of the Collington sand is a light-brown, medium to coarse sand, having a depth varying from 12 to 18 inches. It is underlain by a reddish-yellow medium sand subsoil. A small amount of glauconite is found in the deeper portions of the subsoil. In the Hartford area the total depth of surface soil and subsoil amounts to 6 feet or more over the greater part of the type.

The Collington sand occupies slopes and rolling, elevated positions. It is excessively drained and not well suited to agricultural uses. The greater part of its area is used to supply molding and builder's sand and agriculture is not well developed.

Collington sandy loam.—The Collington sandy loam in the vicinity of Hartford consists of the normal soil and a deep phase. The normal soil does not differ materially from the areas of the type as described for the Freehold area. The deep phase differs enough to warrant separate description. The soil is a yellowish, loamy sand. It is underlain at a depth of 14 to 30 inches by a yellow to reddish-yellow, friable sandy clay, which becomes compact and slightly tinged with green at 30 to 36 inches below the surface. The type occurs on level uplands and is well drained. It consists practically of a gradation between the normal Collington sandy loam and the Collington sand.

Collington fine sandy loam.—The surface soil of the Collington fine sandy loam, to a depth of about 12 inches, is a dark-brown fine sandy loam. In the vicinity of Masonville it grades almost directly into a somewhat sticky coherent fine sandy loam, which is in turn underlain by a stiff, brown loam, or sandy clay subsoil. The entire subsoil has a considerable content of greensand.

Both level and sloping areas of the type occur in the Hartford area. Drainage is fairly well established.

The agricultural uses of the soil for orcharding, special crop production, and general farming are fairly representative of more extensive areas of the type elsewhere in southern New Jersey.

Elkton loam.—The surface soil of the Elkton loam is a light-brown to ash-colored heavy silty loam having a depth of 12 to 15 inches. The subsoil is a slightly heavier silty loam of a yellowish color becoming mottled yellow and gray at a depth of 24 to 36 inches.

The type occupies level to depressed areas of small extent, associated with the Sassafras loam and other upland types. It has a tendency to become baked and puddled when thoroughly dry at the surface and would be decidedly benefited by artificial drainage.

Portsmouth sandy loam.—The surface soil of the Portsmouth sandy loam, to an average depth of 6 to 9 inches, is a dark-gray to almost black sandy loam. It is usually well charged with partly decayed organic matter. The subsoil is prevailingly an almost white, sticky, sandy loam.

The type occupies depressed areas where drainage has not become well established. Through a considerable part of the year the deep subsoil, at least, is saturated with standing water.

A very small area of this type is found in the Hartford area and it is closely associated with better drained upland soils so that its uses are scarcely distinctive.

In addition to the distinct upland soil types there are quite extensive tracts of land along the walls of the Parker's Creek channel and elsewhere which are too steep and broken for cultivation. These areas are almost without exception timbered and were not considered in the study of the cropping of the different agricultural types.

Some of the creek bottoms were sufficiently extensive to justify mapping. They are moist, subject to inundation at times and liable to receive additions of soil material from time to time. The surface soils were usually dark loams or sandy loams while the deeper subsoils at least consisted of beds of greensand or glauconitic loam or clay. The only agricultural use of this material, mapped as the Freneau loam in the Hartford area, is for pasturage.

All these soils are representative of the same types in other parts of southern New Jersey, and conform for the most part to the general descriptions already given. In the case of the Collington sandy loam alone is there any decided departure from normal. The deep phase of this soil in the greater part of its area in the Hartford map consists of a deep deposit of slightly coherent sand, loose at the surface but loamy below a depth varying from 14 to 30 inches. It is somewhat more droughty than the normal type and rather better suited to special truck or fruit crops than to the staple farm crops.

The absolute and the relative extent of the occupied areas of different soil types are given in Table IV:

TABLE IV.—*Extent of different soil types, Hartford Area.*

Soil.	Area occupied.	Proportion of total occupied area.	Soil.	Area occupied	Proportion of total occupied area.
	Acres.	*Per cent.*		*Acres.*	*Per cent.*
Sassafras loam	938.6	45.2	Collington sand	283.1	13.6
Sassafras sandy loam	532.0	25.6	Elkton loam	30.4	1.5
Collington sandy loam	41.8	2.0	Portsmouth sandy loam	30.4	1.5
Collington sandy loam, deep phase	115.9	5.6	Total	2,078.6	100.1
Collington fine sandy loam	106.4	5.1			

The total area covered by the map comprises 2,259.1 acres, while 2,078.6 acres were upland soils agriculturally occupied or capable of such occupation. The areas of rough broken land along the stream courses and those of the Freneau loam, in the stream bottoms, were not included in the estimation of the cropped acreages. The interpretation of facts is based upon the area of 2,078.6 acres.

USES OF SOILS.

Table V shows the total areas of the soil types and the crops supported by them and the percentage relationships of the tracts cropped or otherwise occupied.

TABLE V.—*Proportion of total area and of the area of each soil type occupied by various crops and groups of crops, Hartford Area.*

Crop group and crops.	All soils.		Sassafras loam.		Sassafras sandy loam.		Collington sandy loam (deep phase).		Collington sandy loam.		Collington fine sandy loam.		Collington sand.		Elkton loam.		Portsmouth sandy loam.	
	Acres.	*Per ct.*	*Acres.*	*Per ct.*	*Acres.*	*Per ct.*	*Acres.*	*Per ct.*	*Acres.*	*Per ct.*	*Acres.*	*Per ct.*	*Acres.*	*Per ct.*	*Acres.*	*Per ct.*	*Acres.*	*Per ct.*
General farm crops	872.1	42.0	494.0	52.6	195.7	36.8	45.6	39.3	13.3	31.6	32.3	30.4	60.8	21.9	17.1	56.3	13.3	43.7
Hay	412.3	19.8	309.7	33.0	57.0	10.7	3.8	3.3	11.4	27.1	15.2	14.3	3.8	1.2	9.5	31.3	1.9	6.2
Pasture	24.7	1.2	5.7	.6	3.8	.7												
Corn	349.6	16.8	157.7	16.8	121.6	22.9	17.1	14.7	1.9	4.5	15.2	14.3	17.1	6.0	7.6	25.0	11.4	37.5
Rye	77.9	3.8	20.9	2.2	13.3	2.5	19.0	16.5					39.9	14.7				
Cowpeas	7.6	.4					5.7	4.9			1.9	1.8						
Truck crops	646.0	31.2	345.8	36.8	184.3	34.6	34.2	29.6	9.5	22.5	34.2	32.1	17.1	6.0	9.5	31.3	11.4	37.5
Potatoes	374.3	18.0	224.2	23.9	112.1	21.1	3.8	3.3	3.8	9.0	11.4	10.7	5.7	2.1	5.7	18.8	7.6	25.0
Tomatoes	148.2	7.1	60.8	6.4	55.1	10.4	11.4	10.0	1.9	4.5	11.4	10.7			3.8	12.5	3.8	12.5
Cabbage	43.7	2.2	30.4	3.2	1.9	.3					11.4	10.7						
Asparagus	24.7	1.2	9.5	1.0	9.5	1.8	3.8	3.3					1.9	.6				
Cantaloupes	19.0	.9	3.8	.5	5.7	1.0	5.7	4.9	3.8	9.0								
Beans	13.3	.6	9.5	1.0			1.9	1.6					1.9	.6				
Watermelons	7.6	.4					7.6	6.5										
Miscellaneous vegetables	5.7	.3											5.7	2.1				
Lettuce	5.7	.3	5.7	.6														
Sweet potatoes	1.9	.1											1.9	.6				
Squash	1.9	.1	1.9	.2														
Fruit crops	224.2	10.3	66.5	7.1	57.0	10.7	30.4	26.2	17.1	40.7	26.6	25.0	20.9	7.4	3.8	12.5	1.9	6.2
Orchard	169.1	8.1	26.6	2.9	57.0	10.7	30.4	26.2	17.1	40.7	13.3	12.5	20.9	7.4	3.8	12.5		
Berries	55.1	2.2	39.9	4.2							13.3	12.5					1.9	6.2
No annual crops	336.3	16.1	32.3	3.5	95.0	17.9	5.7	4.9	1.9	4.5	13.3	12.5	184.3	64.8			3.8	12.5
No crop	220.4	10.6	13.3	1.4	77.9	14.7	1.9	1.6					123.5	43.6			3.8	12.5
Garden and grounds	58.9	2.8	17.1	1.9	15.2	2.9	3.8	3.3	1.9	4.5	13.3	12.5	7.6	2.4				
Forest	57.0	2.7	1.9	.2	1.9	.3							53.2	18.8				
Grand total	2,078.6	99.6	938.6	100.0	532.0	100.0	115.9	100.0	41.8	99.3	106.4	100.0	283.1	100.1	30.4	100.1	30.4	99.9

Freneau loam (chiefly in permanent pasture), 121.6 acres.
Rough broken land (chiefly in forest), 95 acres.

It will be seen from these tables that nearly one-half of the total area occupied consists of loams—the Sassafras loam and the Elkton loam. These more retentive soils are normally used in the section for the production of hay, corn, potatoes, tomatoes, and other staple or late truck crops. The remaining soils grade from a fine sandy loam to a loose, deep sand. The area thus presents a sufficient variation in soil type characteristics to permit of considerable diversity in cropping while at the same time it is dominated by the finer grained and more retentive soils.

The table of occupation acreages is in close accord with what might be expected from the table of soil type acreages. The general farm crops occupy 42 per cent of the area, while truck and fruit crops occupy 41.5 per cent. The large area of land not under cultivation results entirely from the fact that the greater part of the Collington sand is more profitably worked to furnish molder's and builder's sand than as an agricultural soil. A porous sand of this character is too unretentive of moisture to support even the early truck crops to good advantage.

The percentage of crop acreages established by the figures for all types constitutes a normal for the area and region. When comparison of the individual percentages of crop occupation of the different types is made with this standard it is evident that the Sassafras loam is more extensively used for growing the general farm crops than is any other really important type in this locality. It supports general farm crops to the extent of 52.6 per cent of its acreage, as compared with 42 per cent for the entire area and with 36.8 per cent on the Sassafras sandy loam, which is the next most extensive type of soil.

With respect to special or truck crops, the Sassafras loam supports them to the extent of 36.8 per cent of its area as compared with 31.2 per cent for the entire area and 34.6 per cent on the Sassafras sandy loam.

Among specific crops, it is notable that hay occupies the largest area of any single crop for the entire area for the Sassafras loam, Collington sandy loam, and Elkton loam, while it is relatively unimportant as a crop on any other soil type within the limits of this survey.

The potato crop ranks second to hay in total acreage and leads corn slightly. There is a marked concentration of the potato acreage on the Sassafras loam and a slight excess in proportionate acreage on the Sassafras sandy loam. This fact supports the results as obtained from the survey of the detailed area near Freehold. These two types are recognized as especially suited to the growing of the crop. It is known in the Hartford area that the Irish Cobbler matures at a slightly earlier date on the Sassafras sandy loam, but usually gives a larger yield upon the Sassafras loam. In consequence of the higher prices at the earlier dates the cash return per acre is about equal for the two types. Both are more highly esteemed for potato growing than any other soils included in this survey. (Figs. 13 and 14.)

The Sassafras loam is the standard type for corn growing, carrying exactly the same relative percentage as that found for all types. Corn is the leading crop in acreage on the Sassafras sandy loam and the Portsmouth sandy loam and of equal importance with hay on the Collington fine sandy loam.

Orchard and fruit crops are decidedly concentrated on the Collington sandy loam and on the deep phase of that type, while the Sassafras sandy loam is also an important type for fruit culture.

Tomatoes are somewhat concentrated on the Sassafras sandy loam, where they occupy 10.4 per cent of the area of the type; and on the Sassafras loam, where they cover 6.4 per cent. Tomatoes are grown for direct marketing as a truck crop in this section, only the last of the crop usually finding its way to the canning or preserving factories.

The figures of crop usage for these different soils emphasize the fact that the heavier, loamy types are most esteemed for the production of such crops as hay, corn, potatoes, and cabbage (fig. 15); that the sandy loam soils are suited to a wide diversity of crops, being adapted to the general farm crops and to a considerable range of special crops, including fruit, and that the more sandy soils are best devoted to special crop production, notably to the growing of the early truck crops. It is also apparent that the more sandy soils are liable to be too droughty even for such uses.

The soils mapped in the Hartford area may evidently be grouped with respect to their crop utilization as follows:

General-farming soils—Sassafras loam, Elkton loam, and Portsmouth sandy loam. *Truck soils*—Collington fine sandy loam and Collington sandy loam, deep phase. *Fruit soils*—Collington sandy loam. *Mixed-purpose soils*—Sassafras sandy loam.

The Hartford area is thus seen to represent a somewhat varied assortment of agricultural conditions and cropping practices which are demonstrably capable of correlation with the soil types which occupy the area.

Prevalence of general farm crops is due largely to the existence in dominant area of the Sassafras loam, a well-drained but retentive, fertile soil. Specialization toward the production of potatoes and tomatoes as the important cash crops is rendered possible by the dominance of the Sassafras loam and sandy loam. Extensive development of orcharding and fruit growing is favored by the presence of the areas of the Collington sandy loam, deep phase, and the Sassafras sandy loam. Lack of agricultural use of a considerable area of land is specifically due to the presence of a large area of the Collington sand, a type too droughty even for the growing of the early truck crops. Steep sloping areas are left in forest, and poorly drained areas are well utilized for grazing.

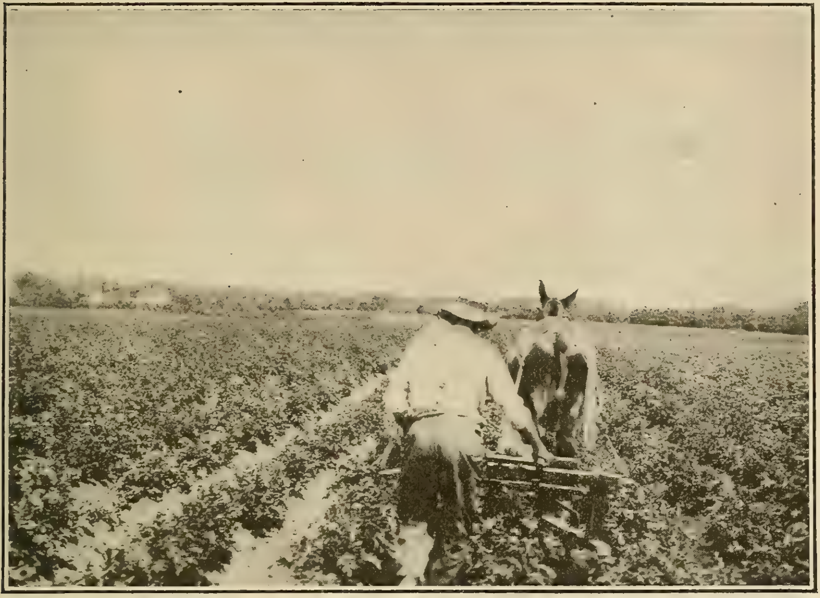


FIG. 13.—Cultivating potatoes (Irish Cobbler) on Sassafras sandy loam, near Hurffville, N. J.

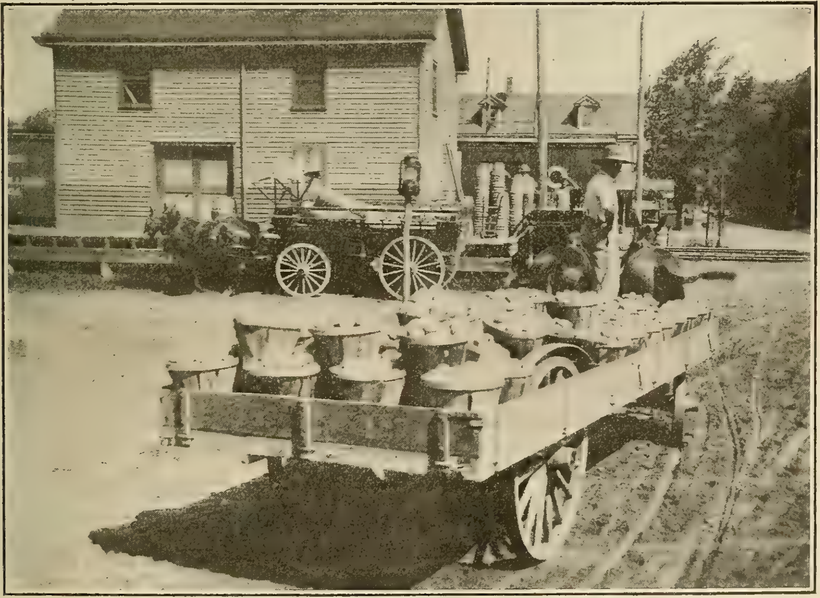


FIG. 14.—Shipping Irish Cobbler potatoes, Hartford, N. J.

In comparison with the Freehold area, the Hartford area is one of greater diversity, both of soil conditions and of resulting crop uses.

SOIL AND CROP SURVEY OF THE THOROFARE AREA.

A combined soil and crop map was made of an area surrounding Thorofare in order to illustrate the relationship between soils and crops in one of the most intensively farmed areas in southern New Jersey.

The Thorofare area is in an angle formed between the Delaware River and the lower course of Woodbury Creek, near its mouth. It lies immediately to the west of Woodbury and about 12 miles southwest of Camden. It is on the West Jersey & Seashore Railroad and easily accessible by highway to the Philadelphia markets. Its accessibility to market is equal to that of the Freehold or the Hartford areas.

Practically all of the area selected lies on the low terrace which borders the Delaware River and only a small tract along the southern border of the map rises to elevations greater than 30 feet above tide level.

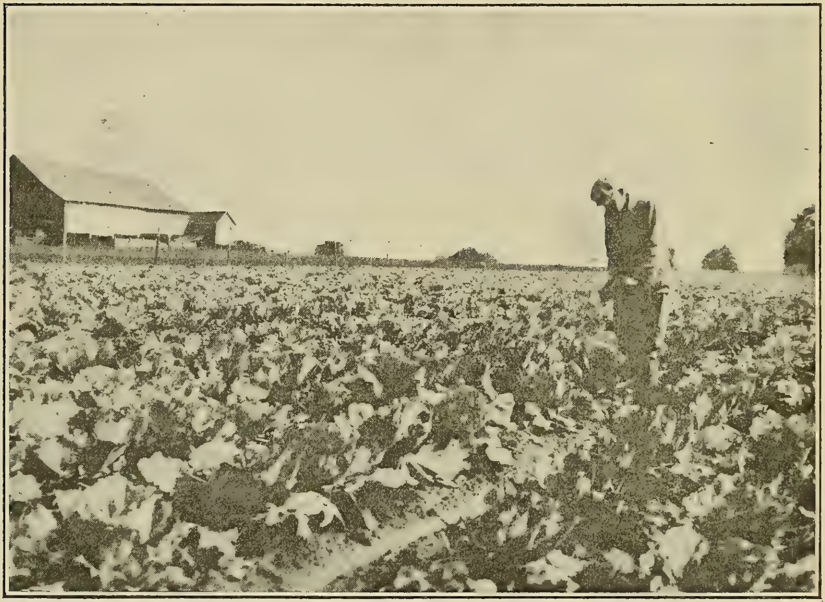


FIG. 15.—Late cabbage on Collington fine sandy loam, near Moorestown, N. J.

The general surface of the upland portion rises gently in a southeasterly direction from the tide marsh which borders the river. Only along Woodbury Creek is there any sharp rise from marsh to upland. There the rise varies from 5 to 25 feet and is accomplished in a low cliff, which gradually becomes lower toward the mouth of the creek.

From the river to Thorofare the surface is a low, slightly undulating plain, the highest altitudes of which are reached between Thorofare and Woodbury Creek in a low ridge reaching to 20 or 25 feet above tide level. Southward from Thorofare a gentle slope toward the interior upland begins, carrying the extreme elevation of the tract mapped to an altitude of 40 feet.

SOILS.

All of the lower part of the area surveyed lies within the terrace formation which borders the Delaware River and Bay. The basal materials in this vicinity consist of two rather heavy beds; one is a black, micaceous clay of massive structure and greasy appearance, which sometimes carries rather large amounts of greensand, while the other, higher bed, is also dark and micaceous but lacks the greensand. Both layers affect the underdrainage of the soil types in the area. Upon the lower terrace, slight hollows and depressions remain more moist than the general condition because of the near presence of the clay. Upon the slopes the upper clay bed sometimes comes near enough to the surface to affect subsoil drainage and to constitute a rather sticky subsoil material underlying the surface soils at varying depths.

The actual soil materials of the greater part of the area are to be ascribed to later stages of the deposition of river or estuarine sediments. These sediments give rise to the sandy and sandy loam soils of the upland. These constitute a thin covering over all but the steepest slopes. The soils of the area thus owe their origin primarily to the deposition of the older, marine beds and to the later covering of these materials by a thin veneer of later river or bay deposits.

Four soil types occupy the arable upland portion of the Thorofare area. These are the Sassafras sand, Sassafras sandy loam, Portsmouth sandy loam, and Collington fine sandy loam. The last covers but a small area. In addition a considerable area of Tidal marsh, some swampy stream bottoms, and the rough, broken land occurring along the slopes from the upland to the streams were necessarily included.

Sassafras sand.—The surface soil of the Sassafras sand consists of a merely, medium sand of a brown to yellowish-brown color and is 6 to 10 inches deep. The surface soil grades into a pale yellowish brown sand, usually rather loose in structure. At a depth ranging from 18 to 24 inches below the surface, the subsoil usually consists of a reddish-yellow to orange fine sand. There is little difference in texture between the surface soil and subsoil. On account of the incorporation of large amounts of organic manures in the surface soil throughout this region the surface soil frequently seems somewhat more coherent and loamy than the subsoil and its color is somewhat darker than the normal for the type.

Near the margins of the Sassafras sand in the Thorofare area and in small depressions throughout its area there are small tracts where the presence of underlying clay becomes evident through the somewhat sticky condition of the deep subsoil. This clay layer aids in the retention of moisture in soil and subsoil while it is usually sufficiently covered by sandy materials to permit of good to excessive drainage of the type.

The surface of the Sassafras sand is nearly level in the Thorofare area. Slight ridging exists, but not sufficient to interfere with cultivation.

The area is representative of considerable tracts of the type which exist along the low terrace bordering the Delaware River, particularly in the vicinity of the mouths of the larger tributary streams. In all of these localities the type is fully occupied for the production of intensively tilled crops. Trucking has been intensively developed on this soil from the vicinity of Burlington, N. J., to that of Penns Grove, N. J. The Thorofare area is representative of this belt.

Sassafras sandy loam.—The Sassafras sandy loam is in most respects identical with the areas described in the Hartford area. It occurs along slopes at the higher elevations near the southern boundary of the Thorofare area. Surface drainage is good, while the heavier subsoil assists in maintaining a good supply of moisture in both soil and subsoil. Practically all of the type is under cultivation.

Collington fine sandy loam.—The surface soil of the Collington fine sandy loam contains a little more fine sand than is typical, owing to a moderate amount of wind action in piling up low ridges of fine sand near the larger streams. The subsoil is a dark-brown, greasy clay to a depth of 18 inches, where it is underlain by a brown loam or clay loam distinctly marked by the presence of greensand.

The surface of the type is nearly level and drainage is well established.

Portsmouth sandy loam.—This soil occupies areas where drainage is poorly established. It is marked by a dark, mucky surface soil, as in the Hartford area, and by a gray to nearly white sandy loam subsoil. The latter is nearly always saturated with standing water.

Swamp.—The areas mapped as Swamp consist of small tracts of poorly drained stream bottoms. They are either timbered or used for pasture. No tilled crops are grown upon them.

Tidal marsh.—Extensive areas of Tidal marsh border the upland both along Woodbury Creek and along the Delaware River. In favorable situations these areas have been diked and drained and some areas of hay are annually cut. The chief use is for pasture, and adjacent upland farms, devoted to truck growing, frequently maintain some dairy cows from the pasturage and forage crops furnished by the diked lands. The areas of Tidal marsh are not included in the measurements of the detailed crop and soil map.

None of these soils differ materially from their normal characteristics in southern New Jersey, except that the outer margins of the Sassafras sand areas show a sticky clay underlying the type at a depth ranging from 24 to 36 inches. This narrow belt of land expresses the thinning out of the material and the near approach to the surface of the older, underlying clay beds.

A part of the Tidal marsh is diked and used for hay production and for grazing. The swampy stream bottoms are used for grazing, while the steeper slopes from upland to stream bottom are chiefly in forest. Nearly every available acre of upland is occupied by some crop or by the homestead and necessary lanes.

The total and relative areas of the different soils are shown in Table VI:

TABLE VI.—*Extent of different soil types, Thorofare area.*

Soil type	Area occupied.	Proportion of total occupied area.
	Acres.	*Per cent.*
Sassafras sand	940.5	69.3
Sassafras sandy loam	248.9	18.3
Portsmouth sandy loam	123.5	9.1
Collington fine sandy loam	45.6	3.3
Total	1,358.5	100.0

USES OF SOILS.

In the Thorofare area the Sassafras sand dominates; the Sassafras sandy loam is the only other important upland soil, and the Portsmouth sandy loam and the Collington fine sandy loam are areally of decidedly less importance. The study of the crop uses of the soils of this area is essentially a study of contrasts between the Sassafras sand and the Sassafras sandy loam.

The character of the agriculture supported by the more sandy soils along the low terrace which borders the Delaware River from Trenton to the vicinity of Penns Grove is well represented by the soil and crop map of the Thorofare area.

Table VII shows the absolute and relative importance of each crop within the area surveyed and upon each of the tilled, upland soil types.

TABLE VII.—*Proportion of total area and of the area of each soil type occupied by various crops and groups of crops, Thorofare Area.*

Crop group and crop.	All soils.		Sassafras sand.		Sassafras sandy loam.		Portsmouth sandy loam.		Collington fine sandy loam.	
	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.
General farm crops	260.3	19.1	81.7	8.7	127.3	51.1	47.5	38.5	3.8	8.3
Corn	102.6	7.6	51.3	5.5	41.8	16.8	9.5	7.7	....	......
Hay	95.0	7.0	15.2	1.6	43.7	17.5	32.3	26.2	3.8	8.3
Alfalfa	7.6	.5	7.6	.8	....	......	....	......	....	......
Pasture	7.6	.5	....	......	3.8	1.5	3.8	3.1	....	......
Oats	19.0	1.4	1.9	.2	17.1	6.9	....	......	....	......
Rye	15.2	1.1	5.7	.6	9.5	3.8	....	......	....	......
Wheat	13.3	1.0	....	......	11.4	4.6	1.9	1.5	....	......
Truck crops	855.0	62.9	693.5	73.6	77.9	31.2	49.4	39.7	34.2	75.0
Asparagus	195.7	14.4	191.9	20.4	1.9	.7	1.9	1.5	....	......
Sweet potatoes	165.3	12.2	153.9	16.4	7.6	3.1	3.8	3.1	....	......
Tomatoes	146.3	10.7	104.5	11.1	26.6	10.7	5.7	4.6	9.5	20.8
Cantaloupes	104.5	7.7	93.1	9.9	5.7	2.3	....	......	5.7	12.5
Potatoes	57.1	4.2	1.9	.2	32.3	13.0	9.5	7.7	13.3	29.2
Peppers	34.2	2.5	26.6	2.8	1.9	.7	5.7	4.6	....	......
Eggplant	30.4	2.2	26.6	2.8	1.9	.7	1.9	1.5	....	......
Watermelons	26.6	2.0	24.7	2.6	....	......	1.9	1.5	....	......
Onions	24.7	1.9	19.0	2.0	....	......	1.9	1.5	3.8	8.3
Beans	20.9	1.5	19.0	2.0	....	......	1.9	1.5	....	......
Cabbage	13.3	1.0	1.9	.2	....	......	9.5	7.7	1.9	4.0
Cucumbers	13.3	1.0	11.4	1.2	....	......	1.9	1.5	....	......
Squash	11.4	.8	9.5	1.0	....	......	1.9	1.5	....	......
Miscellaneous vegetables	11.4	.8	9.5	1.0	....	......	1.9	1.5	....	......
Fruit crops	121.6	9.0	72.2	7.6	36.1	14.5	9.5	7.7	3.8	8.3
Orchard	117.8	8.7	72.2	7.6	34.2	13.8	7.6	6.2	3.8	8.3
Berries	8.1	.3	....	......	1.9	.7	1.9	1.5	....	......
No annual crops	121.6	9.0	93.1	9.9	7.6	3.0	17.1	13.8	3.8	8.3
Garden and grounds	81.7	6.0	66.5	7.1	7.6	3.0	3.8	3.1	3.8	8.3
Forest	28.5	2.1	17.1	1.8	....	......	11.4	9.2	....	......
No crop	11.4	.9	9.6	1.0	....	......	1.9	1.5	....	......
Grand total	1,358.5	100.0	940.5	99.8	248.9	99.8	123.5	99.7	45.6	99.9

Swamp (chiefly pasture), 79.8 acres.
Rough broken land (chiefly forest), 43.7 acres.

Several important facts are made evident by this table: First, the truck crops occupy 62.9 per cent of the total cropped area while the general farm crops cover but 19.1 per cent. Second, the four crops of greatest acreage are asparagus, sweet potatoes (figures 16 and 17), tomatoes, and cantaloupes (figure 18). It is not until fifth place is reached that a general farm crop appears. Corn occupies this position. It should be stated that the field crop, or "horse corn," as it is locally known, and some areas of sweet corn, a truck crop, were both mapped under the single heading. If alfalfa and other classes of hay are combined, the total acreage in hay exactly equals the total acreage in corn. Third, the variety in cropping is also notable (figures 19 and 20). Thirteen different truck crops are grown to an extent sufficient to justify separate mapping within this area of less than 1,500 acres. Seven general farm crops are also grown and orchards occupy an important area. Fourth, the small area covered by forest and by land not in crops is noteworthy. In fact the area given to the necessary grounds and gardens of the homestead is double the area which is otherwise unoccupied by annual crops or orchard.

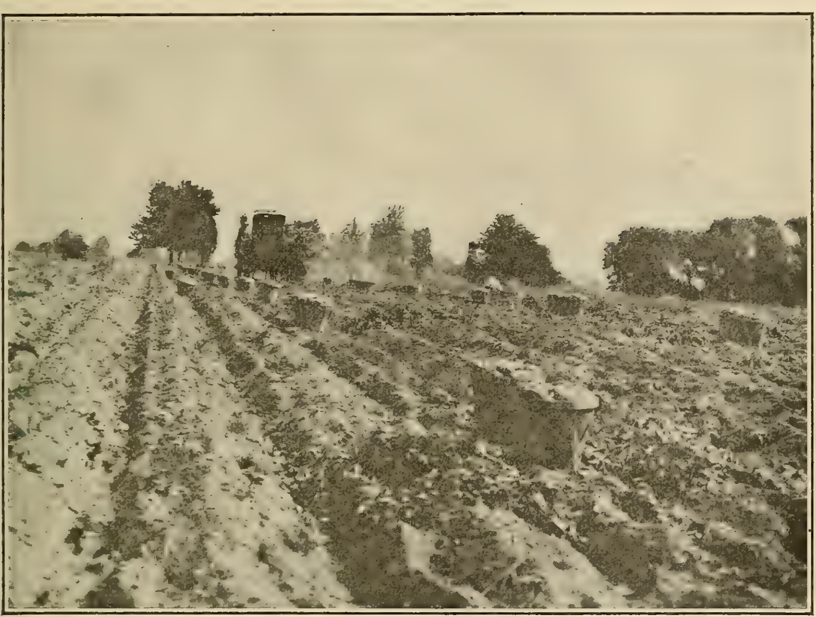


FIG. 16.—Harvesting and sorting sweet potatoes on Sassafras sand, near Thorofare, N. J.

These facts clearly demonstrate the intensity and specialization of the cultivation of the land in the Thorofare area.

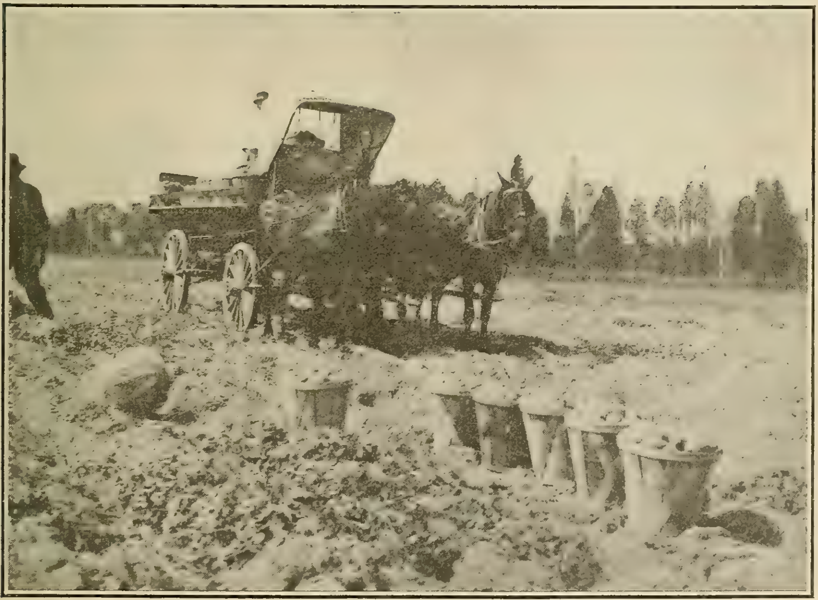


FIG. 17.—Loading early sweet potatoes for the city market, near Thorofare, N. J.

Some very striking features of individual uses of soils for crops are also shown by these tables. The Sassafras sand is the soil preferred by the intensive truck farmer. The truck crops occupy 73.6 per cent of its total area. Asparagus leads in importance, covering 20.4 per cent of the type. Sweet potatoes, tomatoes, and cantaloupes are of decided importance. In fact the acreage given to each of these four crops considerably exceeds that occupied by all of the general farm crops.

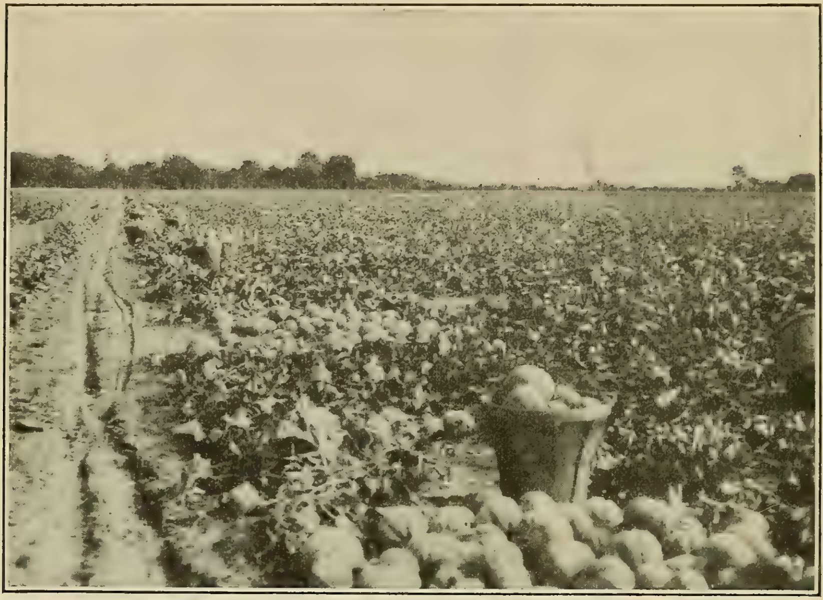


FIG. 18.—Cantaloupes on Sassafras sand, near Clarksboro, N. J.

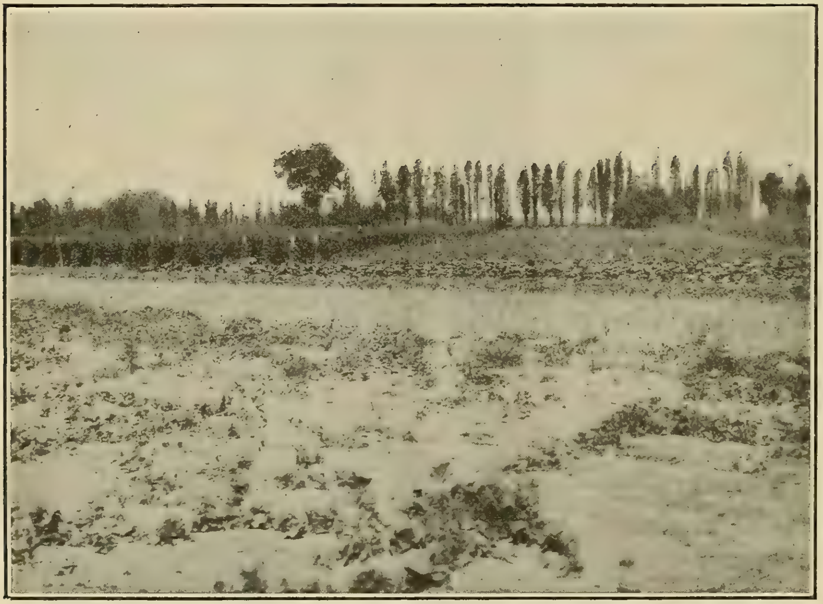


FIG. 19.—Intensive cropping on the Sassafras sand, Thorofare, N. J. A locality of varied crops and small fields.

Yet certain truck crops are discriminated against as markedly as these four are preferred for production on this soil.

Irish potatoes only occupy 1.9 acres on the Sassafras sand, compared with 32.3 acres on the Sassafras sandy loam, or 13 per cent of its area; 13.3 acres on the Collington fine sandy loam, or 29.2 per cent of its area; and 9.5 acres on the Portsmouth sandy loam, or 7.7 per cent of the area of that type. This distinction is in full accord with the conclusions reached in connection with the observations concerning the general region.

The acreage in cabbage is concentrated on the Portsmouth sandy loam—a moist, low-lying soil—this crop appearing only to a limited extent on the Sassafras sand and the Collington fine sandy loam.

The absence of anything but a purely accidental area of asparagus from all soil types except the Sassafras sand is decidedly significant.

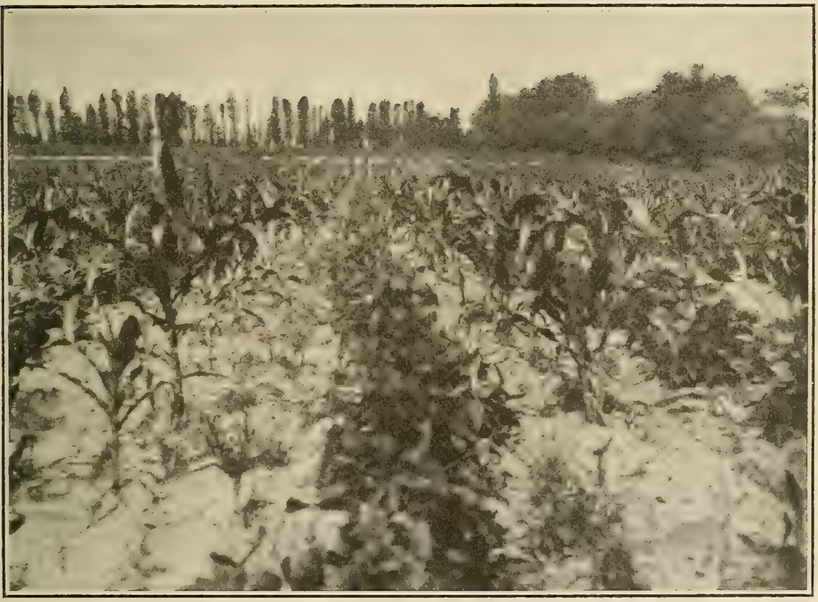


FIG. 20.—Sweet corn interplanted with string beans on Sassafras sand.

Wherever possible the other soils of the area have been avoided for setting asparagus beds and only where small areas of other types were closely associated with this chosen asparagus soil is any acreage of the crop discovered.

The contrast between the crop occupation of the Sassafras sand and the Sassafras sandy loam is marked. The former type is absolutely dominated by truck crops; the latter carried 51.1 per cent of its area in general farm crops. On the former, asparagus is the leading crop; on the latter, hay leads in acreage and corn is a close second. Among truck crops, potatoes cover only 1.9 acres on the Sassafras sand, while they occupy 32.3 acres on the Sassafras sandy loam, a type of approximately one-fourth its total area. It is interesting to note that tomatoes are of almost equal importance upon the two types. But observation shows that the earliest pickings are made on the Sassafras sand while the medium early and the later crops are chiefly harvested from the Sassafras sandy loam. These relationships to the growing of the potato and tomato crops are in accord with the recorded facts of the Hartford area. The Sassafras sandy loam, therefore, may be characterized as a soil well suited to the production of the general farm crops and of considerable value for the production of the mid-season and later truck crops such as tomatoes and potatoes. It is an excellent soil for the use of the farmer who desires to combine the growing of special cash crops with the practice of general farming and fruit growing.

Practically all of the Portsmouth sandy loam in the Thorofare area is so distributed in long, narrow areas that it does not receive distinctive treatment. Yet it is worthy of note that the general farm crops and the truck crops are of almost equal area upon this soil. Hay occupies more than one-fourth of the entire area of the type. Forested areas are next in extent. Corn is grown to an equal extent with cabbage and potatoes. Tomatoes and peppers are the only other important crops grown. Thus, the tendency is toward the growing of general farm crops and late truck crops upon the Portsmouth sandy loam. Where properly drained, the type is well suited to this utilization.

SOIL AND CROP SURVEY OF THE SWEDESBORO AREA.

In order that a study might be made of the soils in an area largely devoted to the growing of sweet potatoes (figures 21 and 22) and tomatoes (figures 23, 24, 25, and 26) in addition to the general farming crops, a detailed map of the soils and crops was made immediately north of Swedesboro, Gloucester County, in the summer of 1915. The map represents the actual crops and soil conditions as they existed between the 1st of July and the 15th of August.

The Swedesboro area is located on the Salem Branch of the West Jersey & Seashore Railroad, about 20 miles south of Camden. It lies along the north bank of Raccoon Creek at a distance ranging from 4 to 6½ miles from the Delaware River, and occupies a rolling and elevated section consisting of three rather distinct topographic features.

The tide rises in Raccoon Creek to the eastern limits of the area surveyed and the immediate banks of the creek are bordered by Tidal marsh, part of which has been reclaimed so that it may be used for pastures and for the cutting of hay, while the remainder furnishes some pasturage at low tide.

Immediately along the flooded areas the ground rises rather sharply to a low terrace which extends interruptedly along the course of the stream. The frontal slope to tidewater areas is usually rather steep, comprising a low cliff which is not included with the tilled upland but is chiefly wooded. Above this frontal slope the terrace rises

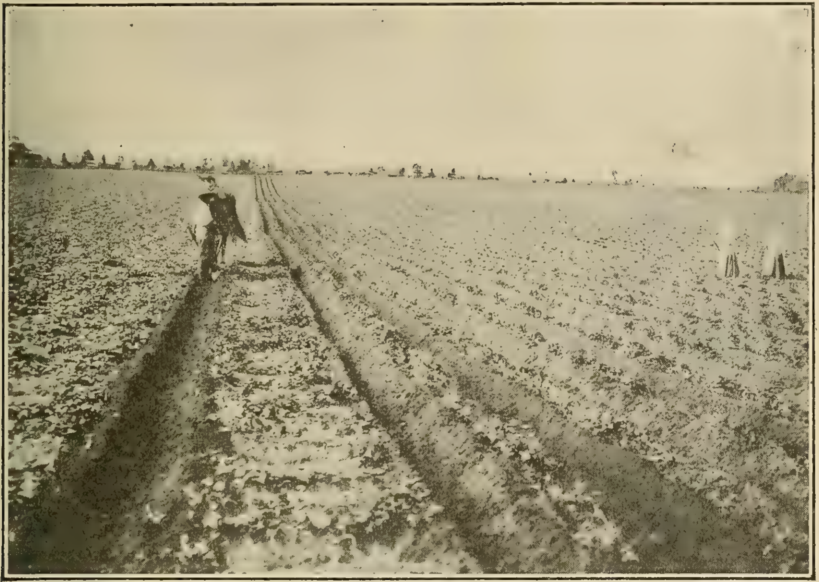


FIG. 21.—Cultivating and ridging up sweet potatoes on Sassafras coarse sandy loam near Swedesboro, N. J.

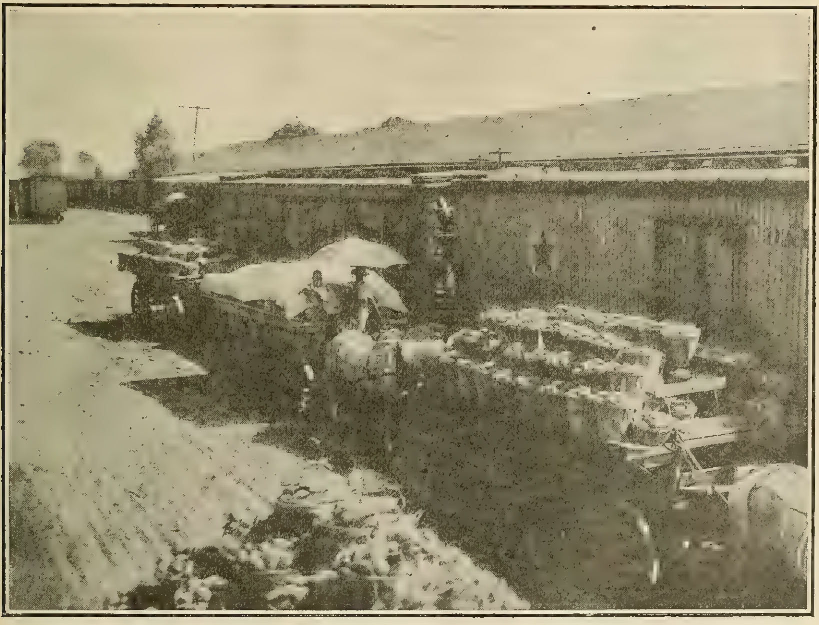


FIG. 22.—Hauling sweet potatoes to Swedesboro, N. J., for shipment. The largest sweet potato shipping point in southern New Jersey.

terrace is crossed by many local streamways and is thus rendered discontinuous and imperfect. It represents an inland extension along Raccoon Creek of the better-defined terrace which borders the Delaware River in this vicinity.

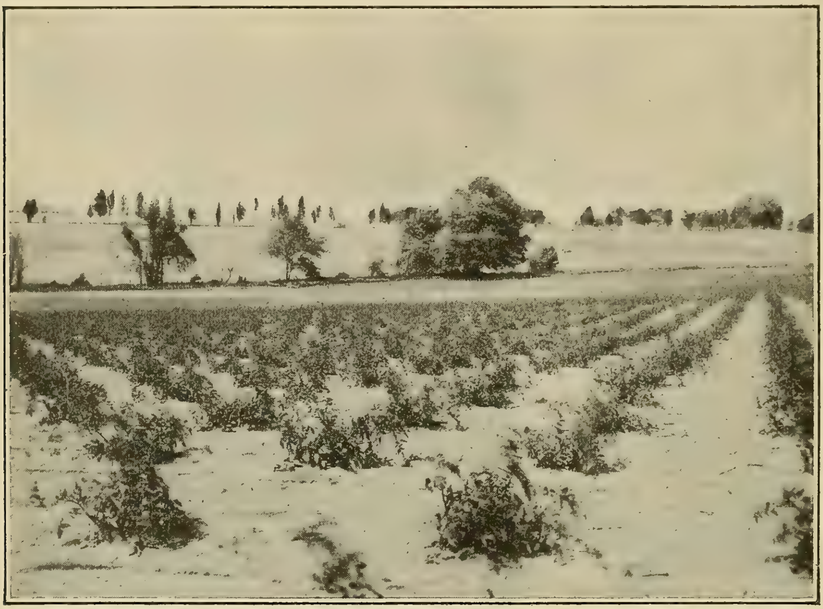


FIG. 23.—Early truck-crop tomatoes on Sassafras sandy loam and Collington fine sandy loam, near Swedesboro, N. J.

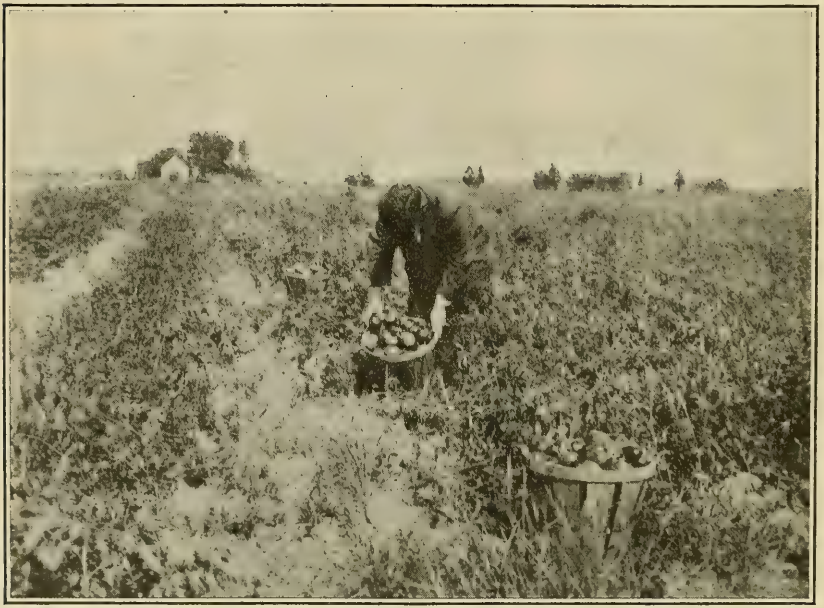


FIG. 24.—A good crop of canning tomatoes on Sassafras fine sandy loam, near Penns Grove, N. J.

Practically all that portion of the area which lies to the northwest of the Woodbury-Salem pike consists of a gently undulating and slightly dissected portion of a higher terrace. This terrace also extends to the southeast of the pike to a distance ranging from one-fourth to one-half mile. The general level of the surface of this physical division varies between 50 feet and 95 feet above tide level.

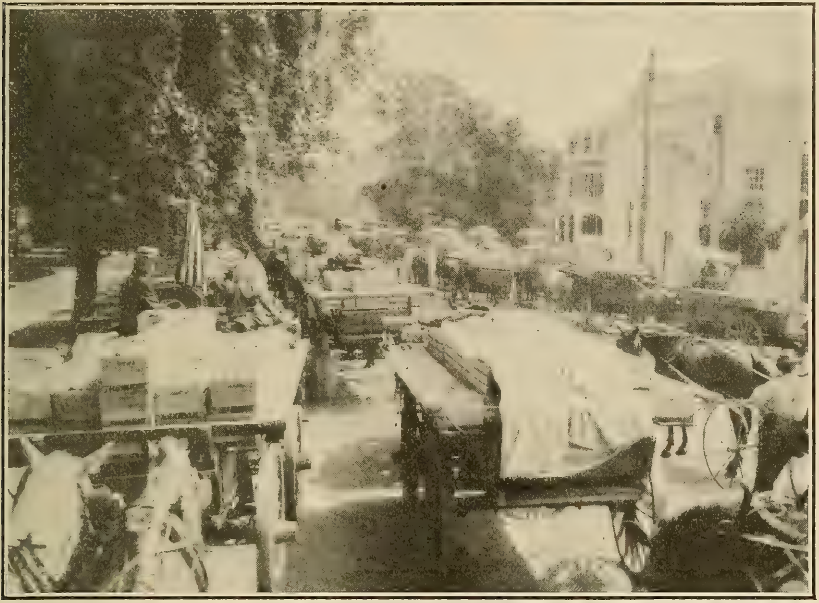


FIG. 25.—Selling truck-crop tomatoes to the highest bidder. A common street scene in Swedesboro, N. J., during July and early August.

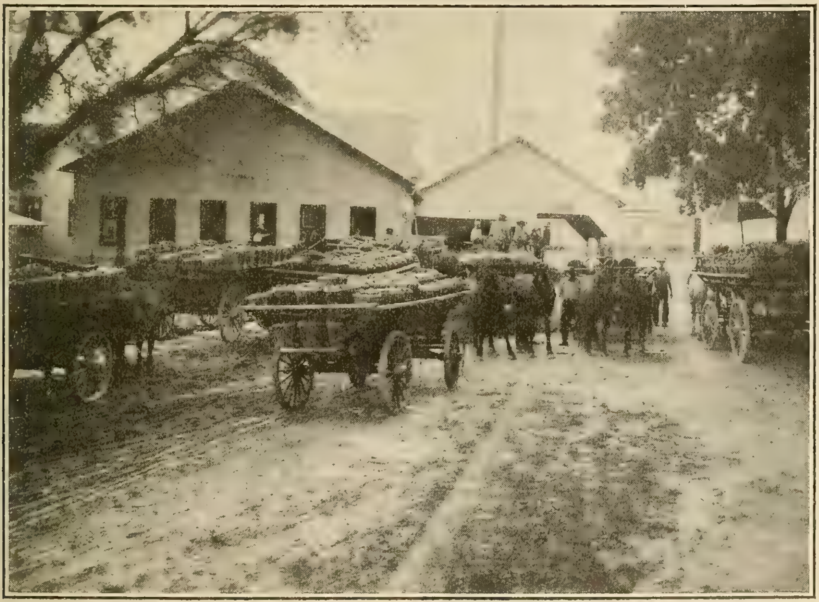


FIG. 26.—Delivering canning-crop tomatoes at a Salem County, N. J., canning factory.

The terrace form is most distinctly seen to the northwest of the pike. Evidences of the same physical feature may be detected at higher levels along the Raccoon Creek drainage in the extreme southeastern corner of the detailed survey.

Rising above any of these elevations, a high ridge of land extends almost from the margin of the Raccoon Creek swamps, northeasterly across the area to its extreme northeastern corner. The summit of this ridge is clearly indicated upon the soil map by the areas occupied by the Colts Neck gravelly sandy loam. From this summit the land surface slopes rather steeply down to the upper levels of the higher terrace.

It is probable that the extreme summit of this higher ridge represents remnants of an older formation which has elsewhere been removed by long-continued erosion. The slopes are undoubtedly formed from soil wash from this higher and partly destroyed formation, mingled with a considerable amount of material which has been brought to its present condition through the weathering of underlying marl formations. Such areas are particularly in evidence in the southeastern third of the area, where considerable tracts of both the Collington fine sandy loam and the Colts Neck loamy sand are found. These two types owe their origin and characteristics to the influence of the underlying marl formations, representing chiefly different degrees of weathering to which the original materials have been subjected. Where the marls are still comparatively fresh they retain much of their original greenish color. Where they have been more thoroughly weathered they have assumed a decidedly reddish tinge, which serves to differentiate the resulting soils as members of the Colts Neck series.

The greater part of the drainage of the area is accomplished through the medium of several small streams. Those found in the eastern and southern parts of the area are tributary to Raccoon Creek. Their courses are relatively short and their gradients are steep. At their lower ends they have cut deep gorgelike channels through the lower terrace. At their upper ends they usually head in slight gullies or in springy areas within the upland. The streams of the remainder of the area flow almost directly to the Delaware River. They also head in springy areas in the upland. The land along their courses through the area mapped in detail is somewhat swampy. Their banks are low but steep.

Drainage is effective over all of the upland, and the run-off is so rapid upon the steeper slopes that heavy rains are likely to do some damage through erosion of soil from the fields.

This is particularly the case along the flanks of the ridge crossing the southeastern corner of the area.

SOILS.

The underlying formations which constitute the basal structure of the Swedesboro area consist of distinct layers belonging to the marl formations which extend across the State from the Raritan Bay to the Delaware River. In the immediate vicinity of Swedesboro these beds consist of a lower layer of dark-colored, nonglauconitic clay, only exposed at the surface in a limited area; of a somewhat glauconitic sand, which underlies the upland along both sides of the Woodbury pike; and of a distinctly glauconitic, or marl sand which occurs along the slopes to Raccoon Creek and also along the slopes from the high ridge to the upper rolling terrace. The marly material from this formation gives rise to the soils of the Collington series either where it outcrops directly at the surface or where the same material has been mixed to any considerable extent with the later terrace materials.

The soil-forming materials of the area are derived chiefly from later river or estuarine deposits which cover the older formations to varying depths, usually ranging from a few inches to an extreme depth of 5 to 15 feet.

The greater part of the soils of the Swedesboro area, including nearly all of the rolling upland of the higher terrace level, has been formed from these later deposits, while the soils of the lower terrace are more recent and have been formed from materials derived from all of the older formations.

Thirteen distinct soils were mapped in the detailed soil and crop map of the Swedesboro area. These fall into four main groups. The most extensive and agriculturally the most important soils belong to the Sassafras series, represented by six different types. The Collington series is represented by two types and a phase of one of them. The Colts Neck series has two soils in the area, while the Portsmouth series is represented by only one. In addition there are accessory areas of Rough, broken land, chiefly in forest, and of Tidal marsh, used for the growing of hay and for pastures.

Sassafras coarse sandy loam.—The surface soil of the Sassafras coarse sandy loam, to an average depth of about 10 inches, consists of a coarse, loamy sand of a brown to yellowish-brown color. There is frequently a scattering of fine gravel over the surface. It does not interfere with cultivation. The subsoil to a depth of 30 to 32 inches is a somewhat more coherent, loamy sand containing some fine gravel. At about 30 inches in depth the subsoil becomes decidedly more coherent and a sticky sandy loam subsoil is encountered.

The surface of the type is either gently sloping or nearly level, although slight depressions exist within its area. Drainage is commonly good to rather excessive. Seepage waters rise nearly to the surface at the foot of slopes, rendering the lower lying portions of the type somewhat more moist than the general average. The natural tendency of the type to excessive drainage has been corrected in the Swedesboro area through the incorporation of large quantities of stable manure and of green crops plowed into the surface soil.

The type is practically all cleared and used for intensive forms of crop production.

Sassafras sandy loam.—The surface soil of the Sassafras sandy loam is a brown, loamy, medium sand, 6 to 8 inches deep. It is somewhat more sandy than in either the Hartford or the Thorofare area. The subsoil is a loamy yellow sand to a depth of about 18 inches, where it is underlain by a sticky, coherent, sandy loam of a reddish-yellow color. This is locally termed a "clay." A small amount of gravel is found in both soil and subsoil.

The surface of the type is gently sloping to nearly level. Drainage is well established but is not usually excessive.

Sassafras gravelly coarse sandy loam.—The Sassafras gravelly coarse sandy loam occupies gravelly slopes and knobs. The surface soil to a depth of 5 to 10 inches is a yellowish-brown sandy loam filled with fine gravel. The pebbles range in size from one-fourth to 1½ inches in diameter. The immediate subsoil is a yellow, gravelly loamy sand or gravelly sandy loam. The deeper subsoil usually consists of a somewhat compacted and dense gravel bed containing only a moderate amount of finer grained material.

The type occurs on slopes or as small knolls and knobs, and drainage is complete to excessive.

Sassafras coarse sand.—The surface soil of the Sassafras coarse sand, to an average depth of about 8 inches, is a brown to yellowish-brown coarse sand. It is scarcely coherent and constitutes the most sandy soil in the area. The subsoil, extending from a depth of 8 to 36 inches, consists of a medium yellow sand, slightly orange in color in the lower depths. A small amount of fine gravel occurs in the deep subsoil.

The type occurs chiefly on low ridges associated with the Sassafras coarse sandy loam and sandy loam. It is well to excessively drained.

Sassafras fine sandy loam.—The surface soil of the Sassafras fine sandy loam, to a depth of about 8 inches, is a brown fine sandy loam containing small quantities of fine gravel. From 8 to 16 inches the subsoil is a reddish-yellow, sticky, fine sandy loam. This is underlain to a depth of 3 feet or more by a stiff reddish-yellow clay.

The surface of the type is gently sloping and the drainage is good. The stiff subsoil interferes somewhat with internal drainage.

Sassafras loam.—The Sassafras loam is not typical in the Swedesboro area, comprising only two small tracts of loamy wash from the upland, accumulated in slight hollows.

Colts Neck loamy sand.—The surface soil of the Colts Neck loamy sand, to a depth of about 8 inches, is a reddish-brown loamy sand. The coarse and medium grades of sand are plentiful and a small admixture of fine gravel occurs in the surface soil. The subsoil, to a depth of about 20 inches, is a reddish-brown to reddish-yellow rather coarse loamy sand. At a depth of 20 to 28 inches this grades into a sticky, mortarlike sandy loam of a decidedly reddish color. A small amount of gravel is present in the subsoil and in the lower part there is a tendency toward cementation by iron salts.

The type occupies gentle slopes along the ridge which crosses the area. The greater part of the type lies well for cultivation, but small tracts are rather steeply sloping and inclined to become washed by heavy rains. Drainage is excellent.

This is the principal "red land" soil in the region, and it is especially esteemed for the growing of sweet potatoes, which are of the highest quality.

Colts Neck gravelly sandy loam.—The Colts Neck gravelly sandy loam is characterized by a dark, rusty red gravelly loam surface soil, having an average depth of about 5 inches. It is underlain to a depth of 18 inches by a dark-red, sticky, sandy loam, containing a considerable amount of gravel and fragments of iron crust. It is frequently hardened through the deposition of iron salts as cement. Usually below 18 or 20 inches the deep subsoil is a sticky red clay, filled with gravel and broken iron crust. The gravel in this type is a honey-colored quartz gravel ranging in size from one-half inch to 2 inches in diameter.

The Colts Neck gravelly sandy loam occupies the highest ridges in the area and forms separated knolls of some elevation. It has suffered to some extent from erosion and is quite generally left in forest. It has been utilized to a limited extent for peach orchards.

Collington fine sandy loam.—The Collington fine sandy loam does not differ materially in the Swedesboro area from its occurrences in the Hartford and Thorofare areas, except that there are local accumulations of fine sand on some of the slopes which render the total depth of the surface soil greater than is usual. There are within the limits of the Collington fine sandy loam certain steep slopes that have suffered from considerable erosion. On these slopes the surface soil is only 2 or 3 inches thick and in many cases the compact subsoil is exposed. This phase is of no great importance either in the Swedesboro area or elsewhere in southern New Jersey.

Collington gravelly sandy loam.—The surface soil of the Collington gravelly sandy loam, to a depth of about 6 inches, is a brown sand, well filled with small white quartz pebbles. The subsoil, to a depth of about 24 inches, is a greenish-yellow gravelly sand. It is usually compact and so filled with gravel as to be almost impenetrable. This rests upon a greenish-yellow sticky sandy loam or upon the unweathered greensand at a depth of about 24 inches.

The type occurs as narrow bands and small scattered areas associated with the Collington fine sandy loam.

Where the type occurs as narrow belts in better arable soils it is tilled. Along the margins of areas or on stream slopes it is usually left in forest.

Portsmouth sandy loam.—This type is the same as described in the Hartford and Thorofare areas. It occurs only around stream heads where drainage has been partially established. Where drained it is used for growing general farm crops.

Small areas of the Hyde sandy loam, of the Freneau sandy loam, and of fresh-water swamp were also mapped, together with the upland types. They are chiefly or entirely used for pasture and their area is not considered in detail in the discussion of the upland soils and their crop uses.

The total and relative areas of the different upland soils is shown in Table VIII:

TABLE VIII.—*Extent of different soil types, Swedesboro area.*

Soil.	Areas occupied.	Proportion of total occupied area.
	Acres.	*Per cent.*
Sassafras coarse sandy loam	932.9	37.5
Sassafras sandy loam	638.4	25.6
Sassafras gravelly coarse sandy loam	119.7	4.8
Sassafras coarse sand	117.8	4.8
Sassafras fine sandy loam	13.3	.5
Sassafras loam	3.8	.2
Colts Neck loamy sand	319.2	12.8
Colts Neck gravelly sandy loam	79.8	3.2
Collington fine sandy loam	127.3	5.1
Collington fine sandy loam, eroded phase	19.0	.7
Collington gravelly sandy loam	22.8	.9
Portsmouth sandy loam	96.9	3.9
Total	2,490.9	100.0

It will be observed that while there is a considerable variety both in the origin and in the texture of the different soils as mapped, yet the area as a whole is dominated by sandy and sandy loam soils, and that the soils of the Sassafras series are of the greatest importance, two types of that series comprising 63.1 per cent of the total area mapped. The Colts Neck loamy sand and the Collington fine sandy loam are the only types of any extent which do not fall within the limits of the Sassafras series. Nearly 76 per cent of the total area is covered by three types. These are the Sassafras coarse sandy loam, 37.5 per cent; the Sassafras sandy loam, 25.6 per cent; and the Colts Neck loamy sand, 12.8 per cent.

USES OF SOILS.

The table showing the extent of the different soil types gives an indication of the prevalently sandy nature of the soils included in the Swedesboro area. Table IX, giving crop acreages, reflects the nature of the soils, since it shows that 52.6 per cent of the total area of occupied land is given to the growing of truck crops, while only 37.1 per cent is utilized for the general farm crops.

TABLE IX.—*Proportion of total area and of the area of each soil type occupied by various crops and groups of crops, Swedesboro area.*

Crop group and crop.	All types.		Sassafras coarse sandy loam.		Sassafras sandy loam.		Colts Neck loamy sand.		Collington fine sandy loam.	
	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.
General farm crops	923.4	37.1	342.0	36.6	275.5	43.2	89.3	28.0	34.2	26.9
Corn	385.7	15.5	123.5	13.2	127.3	20.0	32.3	10.1	22.8	17.9
Hay	264.1	10.6	123.5	13.2	83.6	13.1	26.6	8.3	1.9	1.5
Alfalfa	45.6	1.8	15.2	1.6	15.2	2.4	3.8	1.2	1.9	1.5
Pasture	138.7	5.6	41.8	4.5	32.3	5.0			7.6	6.0
Rye	41.8	1.7	26.6	2.9	5.7	.9	7.6	2.4		
Cowpeas	36.1	1.4	1.9		11.4	1.8	17.1	5.4		
Wheat	7.6	.3	7.6	.8						
Oats	3.8	.2	1.9				1.9	.6		
Truck crops	1,311.0	52.6	499.7	53.5	304.0	47.6	207.1	65.0	76.0	59.8
Sweet potatoes	560.5	22.5	205.2	22.0	155.8	24.4	79.8	25.0	30.4	23.9
Tomatoes	364.8	14.7	121.6	13.0	89.3	14.0	55.1	17.3	30.4	23.9
Asparagus	191.9	7.7	91.2	9.8	20.9	3.3	53.2	16.7	11.4	9.0
Potatoes	55.1	2.2	19.0	2.0	17.1	2.6	1.9	.6		
Cantaloupes	55.1	2.2	34.2	3.7	3.8	.6	7.6	2.4	1.9	1.5
Watermelons	26.6	1.1	7.6	.8	3.8	.6	5.7	1.8	1.9	1.5
Squash and pumpkins	24.7	1.1	1.9	.2	9.5	1.5	1.9	.6		
Peppers	15.2	.6	3.8	.4	3.8	.6				
Onions	7.6	.3	7.6	.8						
Eggplant	5.7	.2	3.8	.4			1.9	.6		
Miscellaneous vegetables	3.8	.2	3.8	.4						
Fruit crops	102.6	4.1	55.1	6.0	24.7	3.9	9.5	3.0		
Orchard	93.1	3.7	45.6	5.0	24.7	3.9	9.5	3.0		
Berries	9.5	.4	9.5	1.0						
No annual crop	153.9	6.1	36.1	3.9	34.2	5.3	13.3	4.2	17.1	13.4
Garden and grounds	81.7	3.2	22.8	2.5	26.6	4.1	7.6	2.4	11.4	9.0
Forest	41.8	1.7	7.6	.8	5.7	.9	1.9	.6		
Nocrop	30.4	1.2	5.7	.6	1.9	.3	3.8	1.2	5.7	4.4
Grand total	2,490.9	100.1	932.9	100.0	638.4	100.0	319.2	100.0	127.3	100.0

Hyde sandy loam (in pasture and hay), 7.6 acres.
Freneau loam (chiefly in pasture), 79.8 acres.
Rough broken land (chiefly in forest), 57 acres.

TABLE IX.—*Proportion of total area and of the area of each soil type occupied by various crops and groups of crops, Swedesboro area*—Continued.

Crop group and crop.	Sassafras gravelly coarse sandy loam.		Sassafras coarse sand.		Portsmouth sandy loam.		Colts Neck gravelly sandy loam.	
	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.
General farm crops	43.7	36.4	36.1	30.6	55.1	56.1	32.3	40.3
Corn	24.7	20.6	17.1	14.5	11.4	11.7	20.9	26.1
Hay	7.6	6.3	13.3	11.3	3.8	3.9	3.8	4.7
Alfalfa	1.9	1.6	5.7	4.8			1.9	2.4
Pasture	7.6	6.3			39.9	41.1		
Rye							1.9	2.4
Cowpeas	1.9	1.6					3.8	4.7
Truck crops	66.5	55.4	77.9	66.0	19.0	19.5	22.8	28.5
Sweet potatoes	32.3	26.9	38.0	32.0	1.9	2.0	11.4	14.3
Tomatoes	19.0	15.8	20.9	17.8	5.7	5.8	3.8	4.7
Asparagus	3.8	3.2	9.5	8.0			1.9	2.4
Potatoes	3.8	3.2			5.7	5.8		
Cantaloupes	1.9	1.6	3.8	3.2			1.9	2.4
Watermelons							3.8	4.7
Squash and pumpkins	5.7	4.7	3.8	3.2	1.9	2.0		
Peppers			1.9	1.6	3.8	3.9		
Fruit crops	1.9	1.6	1.9	1.6	1.9	2.0	7.6	9.5
Orchard	1.9	1.6	1.9	1.6	1.9	2.0	7.6	9.5
No annual crop	7.6	6.4	1.9	1.6	20.9	21.6	17.1	21.4
Garden and grounds	3.8	3.2	1.9	1.6	1.9	2.0	1.9	2.4
Forest					15.2	15.7	11.4	14.3
No crop	3.8	3.2			3.8	3.9	3.8	4.7
Grand total	119.7	99.8	117.8	99.8	96.9	99.8	79.8	99.7

Crop group and crop.	Collington gravelly sandy loam.		Collington fine sandy loam (eroded phase).		Sassafras fine sandy loam.		Sassafras loam.	
	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.
General farm crops	3.8	16.7	7.6	40.0			3.8	100.0
Corn			5.7	30.0				
Pasture	3.8	16.7	1.9	10.0			3.8	100.0
Truck crops	15.2	66.7	11.4	60.0	11.4	85.7		
Sweet potatoes	1.9	8.3	3.8	20.0				
Tomatoes	9.5	41.7	3.8	20.0	5.7	42.9		
Potatoes	3.8	16.7			3.8	28.5		
Watermelons			3.8	20.0				
Peppers					1.9	14.3		
No annual crop	3.8	16.6			1.9	14.3		
Garden and grounds	1.9	8.3			1.9	14.3		
No crop	1.9	8.3						
Grand total	22.8	100.0	19.0	100.0	13.3	100.0	3.8	100.0

With reference to specific crops, sweet potatoes lead all other crops in acreage, followed in order of extent by corn, tomatoes, and hay. The large acreage of pasture arises from the fact that mowing lands are grazed in rotation in this area before being plowed for the growing of a tilled crop. Asparagus ranks next to these crops in acreage, while the other truck crops are found in subordinate though important acreages.

As in the Thorofare area, the Irish potato crop is decidedly of minor importance upon the sandy soils.

It is probable that the grain crops would have been recorded in considerably greater area if the survey had been made earlier in the year, since rye is very commonly grown as a winter cover crop, either to be turned under as a green manure or to be cut as a forage crop. In general the small grains are neither suited to production upon the soils of this locality nor able to compete in acreage value with the truck crops, corn, or alfalfa, so that the area of the more sandy soils devoted to them is small.

The section immediately around Swedesboro furnishes a sharp contrast in this respect to the soils in the vicinity of Woodstown. In that locality the Sassafras loam and sandy loam predominate and the small grains, chiefly wheat, are extensively and profitably grown. The influence of the soil upon the character of cropping is clear.

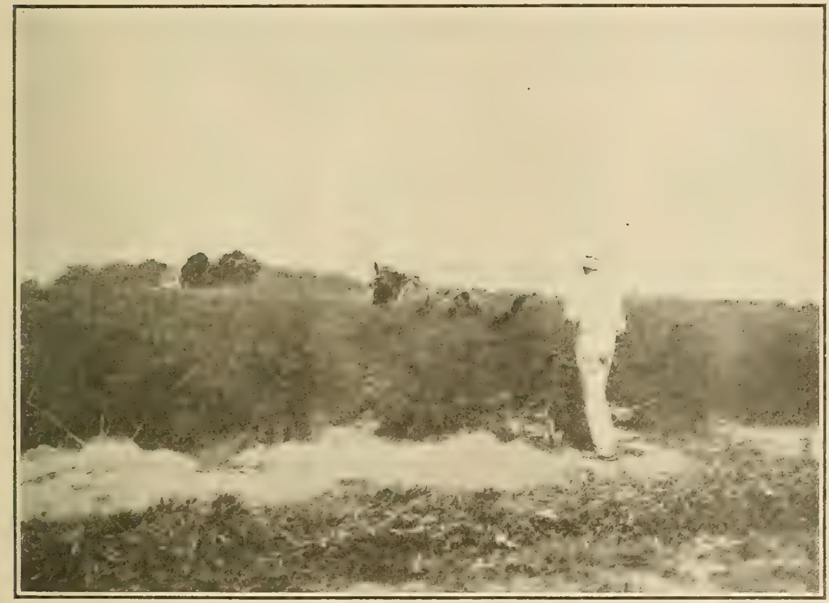


FIG. 27.—Cultivating asparagus on the Sassafras coarse sandy loam, near Swedesboro, N. J.

The Sassafras coarse sandy loam dominates the area, forming 37.5 per cent of the acreage tabulated. In consequence the crop occupation of this type does not differ materially from that shown by the percentages for the entire area. The wide use of this soil for growing a variety of truck crops is demonstrated by the fact that 10 different crops are encountered on the type and that truck crops occupy 53.5 per cent of its entire cropped area. A slight preference for this type for asparagus culture is shown. (Fig. 27.) The desirability of this soil for truck-crop production is well shown by the fact that more than 96 per cent of its area is used for some form of cropping, while truck crops occupy a greater area than all other forms of use. The other general farm crops are grown in well-balanced rotation with them.

The Sassafras sandy loam is the only type of any extent upon which the general farm crops occur in area greater than the standard for all types. Even on this type the truck crops exceed the general farm crops in importance. As in the Thorofare area it is evident that this type is suited to a wide range of crop uses. The fact that a relatively small acreage of asparagus is grown on the Sassafras sandy loam should also be observed. The deeper sandy soils are preferred for that crop as at Thorofare.

The Colts Neck loamy sandy is third in area of the types mapped. Its use for truck crops is distinct, since they occupy 65 per cent of its area. The local preference for this soil for sweet potato growing is also well indicated by the map, 25 per cent of its area being given to that crop. It is also an important soil for growing asparagus and tomatoes.

The Collington fine sandy loam occupies but 5 per cent of the total area of the survey, but is very thoroughly brought under cultivation. Sweet potatoes, tomatoes, and asparagus are the chief truck crops grown upon it, while corn is the only important general farm crop.

The other soil types mapped in the Swedesboro area are relatively of unimportant extent. It is seen that the more sandy soils are chiefly utilized for truck-crop production, while those of heavier texture or those whose natural drainage conditions are not good are chiefly occupied by general farm crops, and that in some instances forest and pasture land dominate. It should be stated that the small area mapped as Sassafras loam is scarcely typical, since it occurs in two small depressions where loamy wash from the upland soils has accumulated. It is only used for pasture and for hay growing.

The facts shown by the Swedesboro map will justify the assertion that the presence of suitable sandy or sandy loam soils, even at some distance from city markets, results in southern New Jersey in the adoption of farm practices which strongly tend toward truck-crop production.

COMPARISON OF THE DETAILED AREAS.

The four areas for which these detailed soil and crop maps were made were selected primarily to secure a representative condition of cropping for each of the more extensive and important soils found in southern New Jersey. It was also found to be possible to locate them in such a manner that contrasts between important soil types and their influence upon cropping and agricultural practice were possible. Thus, the Freehold and Sweedesboro areas may easily be contrasted and the Hartford and Thorofare areas form a couple well suited to the study of the influence of soil upon crop practices.

FREEHOLD AND SWEDESBORO AREAS CONTRASTED.

The Freehold and Swedesboro areas show sharp contrasts in cropping. The two areas illustrate the extremes in development which may be attained in this region as a result of the selection of specific crops suitable to different soils.

The areas included in the two surveys are very nearly the equal in extent. The Freehold area comprises 2,507.1 acres of crops, the Sweedesboro area 2,490.9 acres.

In the Freehold area 93.2 per cent of the area is made up of loam soils or heavier. The Sassafras loam alone occupies 83.7 per cent of the total. In the Swedesboro area practically the entire extent of the area is made up of sandy loam and sandy soils.

In the Freehold area the general farm crops occupy 50.7 of the total area and Irish potatoes cover 39.7 per cent. In the Swedesboro area truck crops cover 52.6 per cent of the area, while the general farm crops drop to 37.1 per cent. The areas in fruit crops are nearly the same for the two areas. The area not planted to crops is slightly higher in the Swedesboro area but in both areas it is practically negligible.

Irish potatoes lead all other crops in acreage in the Freehold area. They are the chief cash crop and they are the special crop most successfully grown on a loamy soil. Moreover, it is known that the dominant soil of the area, the Sassafras loam, is there and elsewhere the preferred potato soil of all New Jersey.

In the Swedesboro area, sweet potatoes occupy the greatest acreage, covering 22.5 per cent of all cropped land. They are grown on the more sandy soils to an extent somewhat greater than upon the sandy loams of that area. Corn is second in importance and then tomatoes follow with a relative extent of 14.7 per cent of the area. In all, 13 truck crops are grown to some extent. Practically no small grains are grown except as cover crops.

The Freehold area is located a little farther from the New York market than Swedesboro is from the Philadelphia market. In both cases access to either market is easy. In both cases a large part of the special crops grown is marketed in other localities than these two cities.

Consequently, the differences in cropping that have been shown to exist in these two cases must be ascribed to the demonstrated differences in soil conditions, possibly modified to a slight degree by the traditions of agriculture in the two localities.

Stated more specifically, the loam soils of the area around Freehold are naturally better adapted to the growing of corn, hay, small grains, and Irish potatoes than to any other products of the soil suited to the prevailing climate. The sandy loam and sandy soils of the area around Swedesboro are inherently better suited to the production of special truck crops, especially sweet potatoes, tomatoes, cantaloupes, asparagus, watermelons, and peppers, than to the production of the majority of general farm crops. Corn and hay may be grown in a supplementary way, and several of the sandy loam types are inherently suited to corn growing. Other types, not so well adapted to general farming under normal conditions have been so well supplied with organic manures in the form of green cover crops plowed under and also stable manure, generously applied, that they are capable of growing corn crops far above their normal capacity.

Both of these areas are representative of considerable regions in southern New Jersey and, so far as reconnoissance observations could be depended upon, they were but intensified illustrations of what may be accomplished upon the same soils wherever they occur in the general region.

HARTFORD AND THOROFARE AREAS CONTRASTED.

Certain contrasts between the Hartford and Thorofare areas have been drawn in part.

In the Hartford area the dominant soils are the Sassafras loam and sandy loam, covering 70.8 per cent of the tilled area. Their occupation by crops is comparable to that of the Freehold area, although differing somewhat in detail. The area as a whole supports 42.0 per cent of general farm crops and 31.2 per cent of truck crops, of which 18 per cent is credited to Irish potatoes. Other truck crops, aside from tomatoes and cabbage, both of which are suited to loam and sandy loam soils, are decidedly unimportant, although the other soils of the area are capable of truck-crop occupation.

In the Thorofare area 69.3 per cent is occupied by the Sassafras sand. The Sassafras sandy loam is the most retentive soil found within the limits of the survey. It occupies 18.3 per cent of the cropped area. The truck crops not only cover 62.9 per cent of the occupied land of the Thorofare area, but four of them—asparagus, sweet potatoes, tomatoes, and cantaloupes—lead all other crops in acreage, ranking in extent in the order named. The acreage planted to asparagus nearly equals that given to the combined area of corn and hay.

Such facts mark the Thorofare area as one of the most highly specialized trucking areas in southern New Jersey. This specialization has been made possible by the existence there of the Sassafras sand.

The general facts shown by the comparison of the Hartford and Thorofare areas are: (1) The areas are equally well situated with respect to climate, markets, and transportation. (2) Loam and sandy loam soils dominate the Hartford area and general farm crops are there more extensively grown than truck crops. Among the latter, potatoes and tomatoes are by far the most important. (3) Sand

and sandy loam soils dominate the Thorofare area. The preponderance of truck crops over general farm crops is marked and four truck crops lead any general farm crop in acreage. Even Irish potatoes are a negligible crop on the Sassafras sand, the chief acreage being grown on the sandy loam.

The conclusion to be drawn is that sandy soils are best suited to the production of truck crops. They are not well suited to the profitable production of general farm crops. These facts are well known in southern New Jersey and the farm practices of the region have become adjusted to them.

Again the differences in cropping which have been shown to exist may be exactly correlated with the differences in the properties of the prevailing soils.

RELATION OF SOILS TO CROP USES IN THE DETAILED AREAS.

The four areas of which detailed soil and crop maps were made in 1914 and 1915 in southern New Jersey show a total measured area of 8,848.5 acres, while 8,919.6 acres of different classes of occupation were recorded. This over-run of occupation above total acreage is due to the fact that interplanting of crops is a common practice in three of the areas. The most notable instances are those in which berries, corn, or truck crops are planted between the rows of orchard trees. There are also many notable instances in which the various truck crops are interplanted. Chief among these are the growing of an early crop of peas with such spacing that tomatoes may be set between the rows, the interplanting of beans or peas between the rows in young asparagus beds, the planting of tomatoes between the rows of young strawberry beds, and the growing of a rapid succession of minor vegetables to aid in making up a varied load of produce on the market wagon.

Naturally, such practices are more evident where intensive trucking prevails and are chiefly to be found in the Thorofare area.

A tabulation of the different soil types encountered in the four soil and crop surveys shows that there are 11 types which are of sufficient extent to be considered dominant soils. There are also 10 other types which are of minor extent. These 21 different types, therefore, are separated into two main groups, the dominant soils, which exert an appreciable influence upon the agriculture of the areas, and the subordinate soils, which are of little agricultural importance within the limits of these surveys.

The dominant soils are arranged into three subgroups. Those soils which are marked by complete surface and internal drainage to such a degree as to tend toward a droughty condition are classed in the sand and coarse sandy loam group. Those which are decidedly retentive of moisture, either through circumstances of texture or because of topographic position, are grouped in the loam and sandy loam group. One type is intermediate in texture and water-holding capacity, and this forms the fine sandy loam group.

The relationships of the dominant and of the subordinate soils to crop production and the relationships of the three groups to each other are shown in Table X:

TABLE X.—*Proportion of total area and of the area of each type occupied by various crops and groups of crops in the four detailed areas.*

DOMINANT SOILS.

Soil and soil group.	Total area measured.	Area in crops, etc.	Truck crops.		General farm crops.		Fruit crops.		No annual crops.	
			Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.
I. Sand and Coarse Sandy Loam Group.	*Acres.*	*Acres.*								
Sassafras sand	934.8	940.5	693.5	73.6	81.7	8.7	72.2	7.6	93.1	9.9
Sassafras coarse sand	115.9	117.8	77.9	66.0	36.1	30.6	1.9	1.6	1.9	1.6
Colts Neck loamy sand	317.3	319.2	207.1	65.0	89.3	28.0	9.5	3.0	13.3	4.2
Sassafras gravelly coarse sandy loam	117.8	119.7	66.5	55.4	43.7	36.4	1.9	1.6	7.6	6.4
Sassafras coarse sandy loam	908.2	932.9	499.6	53.5	342.0	36.6	55.1	6.0	36.1	3.9
	2,394.0	2,430.1	1,544.6	63.6	592.8	24.4	140.6	5.8	152.0	6.2
II. Fine Sandy Loam Group.										
Collington fine sandy loam	275.5	279.3	144.4	51.7	70.3	25.1	30.4	10.9	34.2	12.3
	275.5	279.3	144.4	51.7	70.3	25.1	30.4	10.9	34.2	12.3
III. Loam and Sandy Loam Group.										
Sassafras loam	3,024.5	3,041.2	1,235.6	40.6	1,523.9	50.1	146.6	4.8	135.1	4.4
Portsmouth sandy loam	245.1	250.8	79.8	31.8	115.9	46.5	13.3	5.3	41.8	16.7
Sassafras sandy loam	1,487.4	1,510.1	605.4	40.1	646.1	42.7	120.2	8.0	138.4	9.2
Colts Neck gravelly sandy loam	77.9	79.8	22.8	28.5	32.3	40.3	7.6	9.5	17.1	21.4
Collington sandy loam (deep phase)	108.3	115.9	34.2	29.6	45.6	39.3	30.4	26.2	5.7	4.9
	4,943.2	4,997.8	1,977.8	39.6	2,363.8	47.3	318.1	6.4	338.1	6.7
SUBORDINATE SOILS.										
IV. All Textures.[1]										
Collington sand	281.2	283.1	17.1	6.0	60.8	21.9	20.9	7.4	184.3	64.8
Colts Neck sandy loam	65.9	65.7	13.1	20.0	47.0	71.5	1.6	2.5	4.0	6.0
Collington sandy loam	53.3	55.9	12.7	22.8	24.2	43.3	17.1	30.2	1.9	3.4
Sassafras fine sandy loam	13.3	13.3	11.4	87.5	....	......	....	......	1.9	14.3
Collington fine sandy loam (eroded phase)	19.0	19.0	11.4	60.0	7.6	40.0	....	......	....	......
Colts Neck loam	68.5	68.2	12.2	18.0	52.4	76.8	....	......	3.6	5.2
Collington loam	46.1	42.4	32.0	75.5	9.4	22.1	1.0	2.3	....	......
Elkton loam	30.4	30.4	9.5	31.3	17.1	56.3	3.8	12.5	....	......
Collington clay loam	15.4	15.3	5.6	36.6	4.1	26.8	5.6	36.6	....	......
Collington gravelly sandy loam	22.8	22.8	15.2	66.7	3.8	16.7	....	......	3.8	16.6
	615.9	616.1	140.2	22.8	226.4	36.8	50.0	8.1	199.5	32.3
SUMMARY.										
I. Sand and coarse sandy loam group	2,394.0	2,430.1	1,544.6	63.6	592.8	24.4	140.6	5.8	152.0	6.2
II. Fine sandy loam group	275.5	279.3	144.4	51.7	70.3	25.1	30.4	10.9	34.2	12.3
III. Loam and sandy loam group	4,943.2	4,997.8	1,977.8	39.6	2,363.8	47.3	318.1	6.4	338.1	6.7
IV. Subordinate soils, all textures	615.9	616.1	140.2	22.8	226.4	36.8	50.0	8.1	199.5	32.3
All types, four detailed areas	8,228.6	8,323.3	3,807.0	45.7	3,253.3	39.1	539.1	6.5	723.8	8.7

[1] Freneau loam, of Freehold area, omitted

In this table the total measured area of each type, the area occupied for different purposes connected with agriculture, and the areas and percentages of the different classes of occupation are summarized from the detailed tables given in the presentation of the facts concerning each of the four areas. The same classification of crops is made as in the detailed tables.

The final classification of all soil and crop areas mapped is shown in the summary given in this table.

The notable facts derived from this tabulation may be briefly stated.

With respect to the soils of the sand and coarse sandy loam group, it is shown that truck crops are of chief importance, covering 63.6 per cent of the total cropped area. General farm crops cover only 24.4 per cent, while orchard and other fruit crops cover 5.8 per cent. Only 6.2 per cent of the group is not occupied for the growing of these crops.

In contrast, the soils of the loam and sandy loam group have only 39.6 per cent of their area in truck crops, including Irish potatoes in this class, while 47.3 per cent is in general farm crops and 6.4 per cent in fruit crops. The area not cropped is again small, comprising only 6.7 per cent of the total.

The fine sandy loam group is intermediate between the two other groups, carrying 51.7 per cent of truck crops and 25.1 per cent of general farm crops, but showing 10.9 per cent of fruit crops and 12.3 per cent of area not occupied by annual or orchard crops.

The preferred uses of the different types are capable of a degree of mathematical approximation through a comparison of the relative areas of each crop and group of crops supported by the different soil types. Thus, for truck-crop production the Sassafras sand takes leading rank, with 73.6 per cent of its area occupied by such crops. The other soils of this group are arranged under this type in the order of their relative importance in truck-crop production. The lowest percentages of truck crops found on any soil in the group is 53.5 per cent. It is notable that the three sandy soils in the group considerably outrank the two coarse sandy loams in percentage of truck-crop maintenance This is almost sufficient to justify a subgrouping within the group.

Within the loam and sandy loam group the highest percentages given to any class of truck crops is found on the Sassafras loam with 40.6 per cent of its area given to such crops. This is almost equalled by the Sassafras sandy loam, with 40.1 per cent of the truck crops. In both of these cases the high percentage must be ascribed to the large areas of Irish potatoes grown upon the two types. The growing of other truck crops than potatoes and tomatoes on either of these soils is negligible.

The soils of this group were not arranged, however, with respect to their utilization for truck-crop production, since that is a matter which is of secondary importance in their case. The arrangement is made on the basis of the percentage of their areas given to general farm crops. The Portsmouth sandy loam takes second rank, not so much because of its texture as because of its low-lying topographic position. It is so situated as to be permanently moist and this gives rise to its use for the growing of hay and corn to a degree exceeding what might be expected from its sandy texture.

Without reference to the absolute figures, it should be noted that each type in this group supports a higher percentage of general farm crops than of truck crops.

The single type in the fine sandy loam group is hardly sufficient to form a basis for any decided conclusions beyond the fact that it falls between the extremes set by the sandy soils on the one hand and the more loamy soils on the other.

No very definite conclusions with respect to the crop occupation of the subordinate soils should be drawn from the figures given. It is evident, however, that the Collington sand is found to be too porous and droughty for any large amount of farm occupation. The use of the Collington loam and sandy loam and the Elkton loam for the growing of general farm crops and potatoes is in accord with the general conditions observed over considerable areas of these types included in the reconnoissance work in southern New Jersey.

It is apparent from these tables that soils may be classed according to their textural peculiarities in rather close accord with the fact of crop occupation within an area of well developed and specialized farming such as that of southern New Jersey.

The table shows that the balance between general farming and truck-crop production within these four areas is a graduated matter of soil-texture control. The truck crops dominate the sandy soils, and the general farm crops dominate the loamy soils. There is a fairly definite graduation in the crop occupation of the types from the sandy soils, through the coarser sandy loams and the heavier sandy loams, to the loams at the other end of the scale. The consonance between texture and crop uses is too close through the entire set of dominant soils to be considered as any mere matter of accidental coincidence. Moreover, the four areas are too widely separated geographically to permit one to attribute this consonance to the possible influence of prejudice in soil selection for crop growing as might be the case in a single community more or less wedded to a traditional system of agriculture.

The practical application of the soil-survey classification of soils to the needs of progressive agriculture with respect to the selection of specific crops for definite soils is held to be proved through the results of these surveys of both soils and crops.

RELATIONSHIP BETWEEN SPECIAL CROPS AND DEFINITE SOIL TYPES.

The figures of crop acreages have been tabulated to show the kinds of soils actually used for each of the special crops extensively grown in the territory.

Sufficient areas of potatoes, sweet potatoes, tomatoes, asparagus, and cantaloupes were mapped on the different soils to form a basis for conclusions to be drawn regarding these crops. These constitute by far the most important truck crops grown in southern New Jersey.

These crops and their soil relationships are summarized in Tables XI and XII:

TABLE XI.—*Relation of soils and groups of soils to important special crops, summarized from the tables covering the four detailed areas.*

Type and group.	Total area in crops, etc.	Potatoes.		Sweet potatoes.		Tomatoes.		Asparagus.		Cantaloupes.	
		Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.
I. SAND AND COARSE SANDY LOAM GROUP.	*Acres.*										
Sassafras sand	940.5	1.9	0.0	153.9	16.4	104.5	11.1	191.9	20.4	93.1	9.9
Sassafras coarse sand	117.8	.0	.0	38.0	34.0	20.9	17.7	9.5	8.0	3.8	3.4
Colts Neck loamy sand	319.2	1.9	.6	79.8	25.0	55.1	17.3	53.2	16.4	7.6	2.4
Sassafras gravelly coarse sandy loam	119.7	3.8	3.1	32.3	26.9	19.0	15.8	3.8	3.1	1.9	1.6
Sassafras coarse sandy loam	932.9	19.0	.2	205.2	22.0	121.6	13.0	91.2	9.8	34.2	3.7
The group	2,430.1	26.6	1.1	509.2	20.9	321.1	13.2	349.6	14.4	140.6	5.8
II. FINE SANDY LOAM GROUP.											
Collington fine sandy loam	279.3	24.7	8.5	30.4	10.8	51.3	18.3	11.4	4.1	7.6	2.7
The group	279.3	24.7	8.5	30.4	10.8	51.3	18.3	11.4	4.1	7.6	2.7
III. LOAM AND SANDY LOAM GROUP.											
Collington sandy loam, deep phase	115.9	3.8	3.2	0.0	0.0	11.4	10.0	5.7	5.0	0.0	0.0
Colts Neck gravelly sandy loam	79.8	.0	.0	11.4	14.3	3.8	4.8	1.9	2.4	1.9	2.4
Sassafras sandy loam	1,510.1	200.7	13.3	163.4	10.8	171.0	11.3	32.3	2.1	15.2	1.0
Portsmouth sandy loam	250.8	22.8	9.1	5.7	2.0	15.2	6.0	1.9	.7	.0	.0
Sassafras loam	3,041.2	1,103.6	36.3	.0	.0	60.8	2.0	9.5	.3	.0	.0
The group	4,997.8	1,330.9	26.6	180.5	3.6	262.2	5.2	51.3	1.0	17.1	.3
All dominant soils	7,707.2	1,383.2	17.9	720.1	9.3	634.6	8.2	412.3	5.4	165.3	2.2

TABLE XII.—*Relation of soils and groups of soils to certain secondary special crops, summarized from the table covering the four detailed areas.*

Type and group.	Total area in crops, etc.	Cabbage.		Watermelons.		Peppers.		Beans.		Eggplant.		Onions.	
		Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.
I. SAND AND COARSE SANDY LOAM GROUP.													
Sassafras sand	940.5	1.9	0.0	24.7	2.6	26.6	2.8	19.0	2.0	26.6	2.8	19.0	2.0
Sassafras coarse sand	117.8	.0	.0	.0	.0	1.9	1.7	.0	.0	.0	.0	.0	.0
Colts Neck loamy sand	319.2	.0	.0	5.7	1.8	.0	.0	.0	.0	1.9	.6	.0	.0
Sassafras gravelly coarse sand	119.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Sassafras coarse sandy loam	932.9	.0	.0	7.6	.8	3.8	.4	1.9	.2	3.8	.4	7.6	.0
The group	2,430.1	1.9	.0	38.0	1.5	32.3	1.3	20.9	.8	32.3	1.3	26.6	1.1
II. FINE SANDY LOAM GROUP.													
Collington fine sandy loam	279.3	13.3	4.7	1.9	0.7	0.0	0.0	0.0	0.0	0.0	.0	3.8	1.4
The group	279.3	13.3	4.7	1.9	.7	.0	.0	.0	.0	.0	.0	3.8	1.4
III. LOAM AND SANDY LOAM GROUP.													
Collington sandy loam, deep phase	115.9	0.0	0.0	0.0	0.0	0.0	0.0	3.8	3.2	0.0	0.0	0.0	0.0
Colts Neck gravelly sandy loam	79.8	.0	.0	3.8	4.8	.0	.0	.0	.0	.0	.0	.0	.0
Sassafras sandy loam	1,510.1	1.9	.1	3.8	.2	5.7	.4	.0	.0	1.9	.1	.0	.0
Portsmouth sandy loam	250.8	9.5	3.4	.0	.0	3.8	1.5	1.9	.9	1.9	.8	1.9	.8
Sassafras loam	3,041.2	31.1	1.0	.0	.0	.0	.0	11.4	.4	.0	.0	.0	.0
The group	4,997.8	42.5	.9	7.6	.1	9.5	.1	17.1	.3	3.8	.0	1.9	.0
All dominant soils	7,707.2	57.7	0.7	47.5	0.6	41.8	0.5	38.0	0.5	36.1	0.5	32.3	0.4

The data concerning each crop will be summarized separately.

Irish potatoes.—The figures given in Tables XI and XII show that the Sassafras loam leads all other soils in the absolute acreage of Irish potatoes grown as well as in the relative importance of the crop upon that type. Out of a total acreage of 3,041.2 acres of this type, included in the four detailed surveys, 1,103.6 acres, or 36.3 per cent of the type, was found to be used for Irish potatoes. No other soil included in the surveys approached this in importance in potato growing. The Sassafras sandy loam was second in rank as a potato soil, carrying 200.7 acres in this crop. The relative and absolute importance of potatoes on all other soil types is negligible.

These figures merely give mathematical substantiation of the statements made by Jennings, Patrick, and others that "the Sassafras loam is the preferred soil for the production of Irish potatoes in southern New Jersey."

Sweet potatoes.—All of the soils of the sand and coarse sandy loam group are extensively utilized for sweet potatoes. The Sassafras coarse sand carries the largest percentage of area among soils suited to this crop. Among the sandy loam soils, only the Colts Neck gravelly sandy loam and the Sassafras sandy loam produced any large area or percentage of the crop. These facts are in strict accord with the generally known preference of farmers for a sandy or deep sandy loam soil for the growing of this crop. Not a single acre of sweet potatoes was encountered on the entire extent of 3,041 acres of the Sassafras loam.

Tomatoes.—The soils of the sand and coarse sandy loam group lead in the acreage given to tomatoes, although the loam group is well represented. Compared with its total extent, the Collington fine sandy loam bears a large acreage of tomatoes. It carries 51.3 acres, or 18.3 per cent of its area, in this crop. The Sassafras sandy loam supports the largest absolute acreage in tomatoes, but has only 11.3 per cent of its area in the crop. The Sassafras coarse sandy loam and the Sassafras sand are also important in the growing of tomatoes. They occupy 13 per cent of the area of the former and 11.1 per cent of the latter soil.

Since tomatoes are grown both for direct marketing and for canning, ripening at two distinct periods, there is a wide range in the character of the soils upon which the crop may be grown to advantage. Prevalently sandy and sandy loam soils are chosen for the early and medium early crops, while the more loamy soils are chiefly used for the canning crop.

Asparagus.—The Sassafras sand is the leading type in the growing of asparagus. The type bears 191.9 acres of asparagus, or 20.4 per cent of its total area. The Sassafras coarse sandy loam carried 91.2 acres, or 9.8 per cent of its tilled area, while the Colts Neck loamy sand bears 53.2 acres, or 16.4 per cent of its area in this crop. All three types are decidedly sandy to a depth of 2 feet or more. All three are underlain at a depth ranging from 30 inches to 4 feet by more retentive layers. None of the gravelly soils is used to any extent for this crop.

Cantaloupes.—Cantaloupes are of less importance than the foregoing crops, but are still grown to quite an extent in southern New Jersey.

The Sassafras sand leads in acreage, carrying 93.1 acres, or 9.9 per cent of its area, in cantaloupes. The Sassafras coarse sandy loam is the only other type upon which cantaloupes are important.

The truck crops of secondary importance show some interesting soil relationships.

Cabbage.—The crop maps show a total acreage of 57.7 acres in the four areas. The Sassafras loam leads in cabbage production, with 31.1 acres, and the Collington fine sandy loam is second, with 13.3 acres. These two soils are the only important cabbage soils represented. It is known that soils of the Keansburg series are quite extensively used for growing the crop. It may easily be seen that the heavier loams are preferred for cabbage production. The most notable exception, not shown in the tables, would be that sandy loam soils in a moist position are also chosen for cabbage growing.

Watermelons.—Melons are now grown to a limited extent in the southern New Jersey trucking regions, although formerly the crop was of considerable importance. Only 47.5 acres were encountered in the four detailed surveys. Over one-half of this total occurred on the Sassafras sand, which carried 24.7 acres, or 2.6 per cent of its area, in this crop. All other occurrences of the crop are of minor importance.

Peppers.—The pepper crop is of considerable importance in other sections of southern New Jersey, but only a small area fell within the limits of the detailed surveys. Considerably over one-half of the total acreage in peppers occurs on the Sassafras sand. The other areas are scattering.

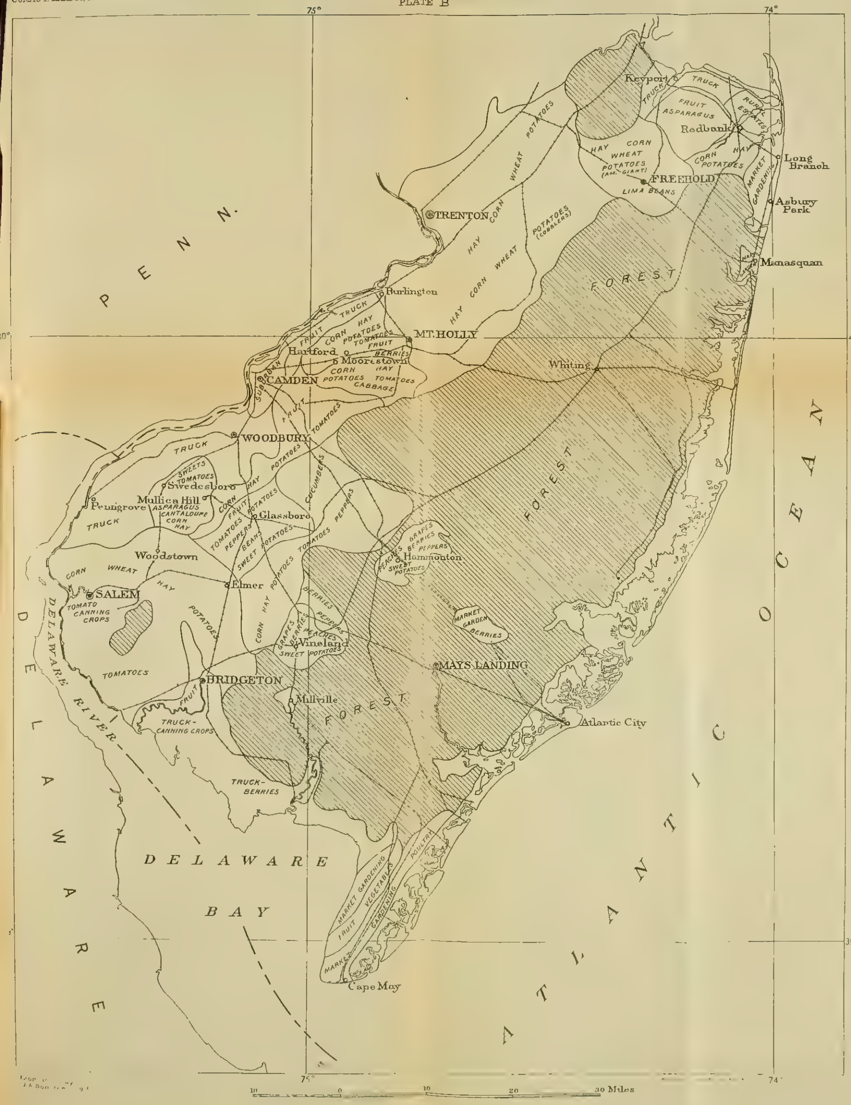
Beans.—Two types lead in the production of beans. These are strongly contrasted in texture. The Sassafras sand carried 19 acres and the Sassafras loam, 11.4 acres, or a total of 38 acres in beans. It is known that if the surveys had been made at a slightly earlier period of the season added areas of beans would have been mapped. The significance of the present figures is, therefore, small. The production of lima beans for canning has already been noted as an exceptional cropping practice on the Sassafras loam near Freehold.

U. S. DEPT. OF AGRICULTURE
BUREAU OF SOILS
MILTON WHITNEY, CHIEF
CURTIS F. MARBUT, IN CHARGE SOIL SURVEY

GENERALIZED CROP MAP

PLATE B

SOUTHERN NEW JERSEY



Bulletin 677, U. S. Department of Agriculture

Eggplant.—Nearly the entire acreage of this crop was found on the Sassafras sand, 26.6 acres out of a total of 36.1 acres being mapped on this type.

Onions.—Nineteen out of a total of 32.3 acres of onions were mapped on the Sassafras sand. The Sassafras coarse sandy loam carries the next largest area, 7.6 acres.

SUMMARY OF SELECTIVE USES AS SHOWN BY THE MAPS.

The selective uses of soils in southern New Jersey, as illustrated by these detailed maps, may be briefly summarized:

(1) For the production of Irish potatoes, the Sassafras loam is the soil preferred over all other types and classes. A sandy loam soil, like the Sassafras sandy loam or the Collington sandy loam, may be used, particularly for an early crop. Sandy soils are distinctly avoided.

(2) The sweet potato crop is produced to the best advantage upon sandy soils or upon rather coarse sandy loams. Taking into consideration the quality of the product, the Colts Neck loamy sand is a leading type. If only considerations of yield are taken into account, then the Sassafras coarse sand and coarse sandy loam are the most important soils for growing the crop. The sandy loams of the series may also be used.

(3) Tomatoes are grown for two distinct purposes, market and canning. The early tomatoes are largely grown on the Sassafras sand, coarse sandy loam, and sandy loam. The later crop for canning is grown on the Sassafras loam and upon the Collington fine sandy loam and sandy loam. The latter fact is not brought out by the tables, but appears from a reconnoissance of the general region.

(4) Sandy soils are preferred for asparagus. The Sassafras sand is a leading type in its production. The Colts Neck loamy sand is second in importance.

(5) Cantaloupes are chiefly grown upon the Sassafras sand, with the Sassafras coarse sandy loam also constituting an important type for this crop.

(6) Cabbage is distinctly a crop to be grown upon the finer textured and more retentive soils, such as the Sassafras loam.

(7) The other minor crops were not sufficiently well represented within the limits of the survey to permit of general conclusions.

SOIL PREFERENCES EXPRESSED BY FARMERS.

In order that the various classes of observations made by field men of the United States Department of Agriculture might be compared with the opinions of a number of representative farmers in southern

New Jersey, letters were sent to nearly 4,000 farmers, principally located within the sections where the detailed soil and crop surveys were made, but also distributed to some extent over other sections of the region.

In these letters inquiries were made concerning the individual preference of each farmer for a sand, sandy loam, loam, or "clay" soil for the growing of each of 14 crops. Additional inquiries were included concerning yields, the use of cover crops for green manuring, the use of stable manure, and the amount and formula of the commercial fertilizer commonly used for the more important crops.

Answers were received from about 1,000 persons. The material thus obtained was classified with regard to the preference for particular soils in the growing of each crop.

Table XIII shows, in terms of the percentage of all answers received, the soil class preferred for the various truck crops:

TABLE XIII.—*Number of answers received, and percentage of preference for each soil class for the various truck crops.*

Crop.	Answers received.	Sand.	Sandy loam.	Loam.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Sweet potatoes	245	61	39	....	....
Watermelons	151	56	41	3	....
Asparagus	163	26	62	10	2
Cantaloupes	178	25	63	12	....
Peas	142	17	62	20	1
Cucumbers	82	10	65	23	2
Eggplant	69	29	45	26	....
Beans	147	13	60	27	....
Peppers	114	7	47	44	2
Tomatoes	359	3	49	42	6
Sweet corn	201	3	38	55	4
Onions	96	5	33	57	5
Potatoes	450	....	34	60	6
Cabbage	187	1	17	71	11

The largest number of answers was received concerning the potato crop. In slightly less than one-half the replies received a definite choice of soil was expressed and 450 decisive answers were tabulated. The answers with respect to tomatoes, sweet potatoes, and sweet corn were also numerous. These four crops lead in acreage among the special crops grown within the territory under consideration.

Some explanation is needed with regard to the soil-texture terms used in connection with these inquiries and answers. In the first place, only soil texture is considered. The classification into soil series is not yet well enough understood nor generally enough used among farmers to permit of more than a broad application to the answers submitted. In the case of the texture of soils the soil survey classification so closely parallels the common usage of farmers that there is little chance for mistake, except where the survey classification goes into greater detail than in the common usage. Hence only four groups were included in the inquiry.

There are only a few unimportant areas of true clay soils in southern New Jersey. The Sassafras loam is the only soil of any great extent within the region which is even popularly known as a clay. This type contrasts rather strongly with the associated sandy soils and has come to be known as a "clay loam" or "clay" in some localities.

It is probable, therefore, that all of the answers designating a preference for a "clay" soil should be added to the loam column to secure exact accuracy.

There is also a local tendency to consider any sandy soil which is not absolutely incoherent as a sandy loam. This is true of many localities where sandy soils prevail. In general, the popular classification of soil textures in this region corresponds fairly well with the more detailed classes used by the soil survey and based upon the physical analyses of the soils.

SOIL PREFERENCES FOR TRUCK CROPS.

The tabulated summary of expressed preferences for the different classes of soil for the growing of truck crops shows that the 14 crops enumerated fall into four rather distinct groups. In making the arrangement, a percentage basis was used in order that the widely differing numbers of answers for the different crops might be equalized. Thus, the percentage of answers expressing a preference for sandy soils for the growing of watermelons is comparable with the percentage of expressed preferences for sandy soil for sweet potato production, although 151 answers were tabulated in the first case and 245 in the latter.

Also, in the first two groups the ranking within the groups is made with respect to the sums of the percentages preferring sand and sandy loam soils, while in the other two groups the ranking is with reference to the sums of the percentages preferring loam or "clay" soils. In both the absolute preferences among the four classes of soils are displayed in detail.

It is evident from this table that the great preponderance of opinion favors the growing of sweet potatoes and watermelons on soils which are distinctly sandy. In the case of sweet potatoes there was no dissent from the preference for soil of these two classes, while the preference for straight-out sand is marked. For watermelons a majority prefer sand.

The second group, including crops for which sandy loam soils are preferred, includes 8 out of the 14 crops for which answers were received. In all cases within this group the sandy loam soils are preferred to any other class, and in three instances—asparagus, cantaloupes, and eggplant—the sandy soil is second to sandy loam in preference. In the other cases, while a sandy loam soil is preferred, yet a loam soil is the expressed second choice. This is particularly marked in the case of peppers and tomatoes, for which there seems to be little preference between a sandy loam and a loam soil.

In the case of tomatoes the geographic distribution of the several answers served to indicate that the sandy loam soils were preferred where the crop was grown for early harvesting as a market crop, while the loam soil was as distinctly preferred in growing the crop for the canning factories.

In this case the crop is grown for two distinctly separate purposes. The truck-crop grower desires to secure a moderately heavy yield of early varieties which will sell at high prices. The main crop is marketed in crates and some of the later pick is marketed at much smaller prices for canning if the conditions are favorable. The grower of tomatoes as a truck crop depends chiefly on early marketing and a high price. He, therefore, prefers a sandy loam soil.

The grower of tomatoes who contracts his crop to the canning factory sets different varieties from the trucker. His sales are usually made on the ton basis and he decidedly depends upon heavy yields for his chances for profits. He, therefore, desires to use a heavier loam soil. For this reason the Sassafras loam has come to be recognized as the leading soil type for the growing of canning tomatoes, as it has been for the growing of Irish potatoes.

In the case of peppers, the crop is used by many truckers as a supplementary crop only. By them it is planted upon land which was not in condition for planting to early tomatoes, to sweet potatoes, or to some other standard early truck crop. Small areas of low, wet land within a sandy or sandy loam field are frequently planted to peppers long after the remainder of the field has been set out to tomatoes or sweet potatoes. In other cases, where peppers constitute a special crop, grown in large acreage, the crop has been found to produce reasonably early fruits on sandy loam soils and also to continue the picking season up to frost limits, when it is planted upon loams. It is therefore a crop grown quite extensively in some localities which are not fitted by the presence of sandy soil for the growing of the standard truck crops. The Sassafras sandy loam and the Sassafras gravelly sandy loam, in southeastern Gloucester County and in adjacent portions of Atlantic and Cumberland Counties, are quite extensively planted to peppers.

It will be noted that asparagus and cantaloupes stand at the head of the crops for which sandy loam to sandy soils are preferred. There is little difference between them with respect to soil choice. The answers received concerning asparagus were grouped somewhat excessively in the southwestern part of the State, where the production of the unblanched stalks is a specialty. It is possible that a stronger tendency toward the use of a decidedly sandy soil would have been recorded if a larger number of answers could have been secured from Monmouth County, where the blanched asparagus is quite extensively grown.

The preference for a sandy loam soil for the growing of peas and beans as early truck crops is marked.

The fact that eggplant is grown on a wide range of soils with some preference for sandy loam types is well reflected in the tabulation of the answers. Probably no other crop but peppers is grown on soils varying so widely in texture as eggplant. Both crops are picked during a prolonged season and the trucker's requirements for a special soil for their production is not so marked as in many other cases.

The group for which a straight-out loam soil is preferred only includes three crops. Two of these are among the most important grown in southern New Jersey.

For sweet corn the preference is decidedly for a loam soil, yet enough truckers are growing the crop in connection with the other early truck crops for 38 per cent of all of the answers to express a preference for a sandy loam soil.

For onions, the loamy soils are preferred, yet a considerable numbers of answers chose the sandy loam soil.

The most extensively grown special crop in southern New Jersey s the Irish potato. For the production of this crop 60 per cent of the correspondents preferred a loam soil and 6 per cent desired a "clay," probably referring to the Sassafras loam. It may, therefore, be said with confidence that two-thirds of the 450 expressed preferences indicate that a loam or heavy loam soil is best for potato growing in southern New Jersey. The remainder of the answers expressed a preference for a sandy loam soil.

These facts correspond very closely with the recorded facts of the crop and soil surveys of the four selected areas. Those surveys disclosed that the greater acreage of potatoes was grown on the Sassafras loam and that the Sassafras sandy loam and Collington fine sand loam were also extensively used for the crop. General observation also shows that the Collington sandy loam should be included in the group of preferred potato soil.

Only one crop is selected for production upon soils heavier in texture than those required for potato growing. The cabbage crop s to be grown either upon a loam or a heavy loam soil, if the preferences of 187 southern New Jersey farmers are followed. This accords well with the facts as observed. The Sassafras loam is used to some extent for growing cabbage. The soils of the Shrewsbury and Keansburg series are also occupied by considerable acreages of cabbage. There is a general tendency in the intensive trucking districts to plant cabbage upon the heaviest and most retentive soils present or to place the crop where small depressions accumulate seepage waters from higher lying areas of sandy loam. Unless the land is actually flooded, the cabbage crop makes good growth upon these moist lands.

COMPARISON OF EXPRESSED PREFERENCE WITH RESULTS OF DETAILED SURVEYS.

A general comparison may be made between the facts as observed in the four detailed areas where distinct soil types and their crop areas were mapped and the preferences as expressed by southern New Jersey farmers as summarized and tabulated. The two sets of results are presented in detail in Tables XI, XII, and XIII.

Irish potatoes.—The crop maps show that 36.3 per cent of the Sassafras loam is occupied by Irish potatoes and that this is the only important truck crop grown on the type. The replies to inquiries show that 66 per cent of the farmers prefer a loam or heavy loam soil for the crop, while 34 per cent wish a sandy loam. The Sassafras sandy loam carried the only other important acreage in potatoes in the mapped area.

Sweet potatoes.—The largest acreages of this crop were mapped on the Sassafras coarse sandy loam, the Sassafras sandy loam, and the Sassafras sand. The sand and coarse sandy loam group of soils carried 509.2 acres of sweet potatoes out of a total of 720.1 acres mapped on the dominant soils. The Sassafras sandy loam carried 163.4 acres of the remainder. The expressed soil preferences show sand preferred by 61 per cent of sweet-potato growers and sandy loam by 39 per cent. The facts from the two sources are well in accord.

Tomatoes.—In the case of this crop the two sets of facts appear to be at some variance. It is held, however, that a fifth survey, made in the vicinity of Salem, N. J., would have corrected this seeming discrepancy, since the Sassafras loam is extensively used in that vicinity for the production of canning tomatoes. The Freehold area produced no tomatoes. The Hartford area included areas grown both for market and for canning. The Thorofare and Swedesboro areas included areas of tomatoes grown almost exclusively for market, and only the residue of the crop after the early tomatoes have been shipped is normally sold for canning. Thus the figures from the four detailed areas throw truck crop tomatoes into undue prominence.

It appears from the tabulated areas that slightly more than one-half of all the area in tomatoes was found on the sand and coarse sandy loam soils. Outside of this group, the Sassafras sandy loam was the only type carrying an important acreage, 171 acres in all.

In the tabulated answers to inquiries, 52 per cent of the replies expressed a preference for a sandy or sandy loam soil for tomato growing, while 48 per cent of the replies indicated a preference for a loam or heavy loam soil. It has already been shown that the latter group corresponds to the canning-crop requirements, while the former indicates the growing of tomatoes as a truck crop.

Sweet corn.—This crop was not mapped separately from field corn in any of the four detailed surveys.

Asparagus.—The mapped areas showed that 349.6 acres of asparagus were grown on the sandy and coarse sandy loam soils. This constitutes 85 per cent of the total acreage mapped. The Sassafras sandy loam carried one-half of the remainder of the total acreage. The answers to inquiries indicate 26 per cent of the farmers distinctly preferring a sand soil and 61 per cent desiring a sandy loam soil for this crop. It may thus be said that the more sandy soils are best for asparagus growing. The existence of a sandy loam deep subsoil was especially required in many of the answers.

Cantaloupes.—The mapped areas of this crop showed 140.6 acres grown on the soils of the sand and coarse sandy loam group. The answers to inquiries indicate a preference for sandy soils to the extent of 25 per cent of the total and for sandy loam soils to the extent of 63 per cent. Loam soils were preferred in 12 per cent of the answers. It will be noted that the Sassafras sand carried 93.1 acres out of a total of 165.3 acres of the crop as mapped. The Sassafras coarse sandy loam and sandy loam carried the other important acreages.

Cabbage.—The Sassafras loam bore 31.1 acres of cabbage out of 42.5 acres mapped. The Portsmouth sandy loam carried 9.5 acres of the remainder. In the answers to inquiries, 71 per cent of the growers preferred a loam, while 11 per cent desired an even heavier soil. The Portsmouth sandy loam, because of imperfect drainage, responds to cropping in a manner similar to an ordinary loam. The agreement of mapped facts and those derived from correspondence is close.

Watermelons.—Within the mapped areas watermelons occurred to the extent of 24.7 acres on the Sassafras sand, out of a total of 47.5 acres mapped. Eighty per cent of the crop was found on the sand and coarse sandy loam group. In the replies to inquiries it was found that 56 per cent of the replies favored a sand soil and 41 per cent a sandy loam.

None of the other minor truck crops were encountered in sufficient area to permit of any very definite conclusions.

Allowing for slight differences in the usage of soil nomenclature as between the popular custom and the professional classification, the correspondence between the two classes of evidence is seen to be striking.

SOIL AND CROP GEOGRAPHY.

The result of all of the facts thus ascertained concerning the distribution of the different soils in southern New Jersey is plotted on the map. (Plate A, page 16.)

The salient facts with respect to crop distribution are similarly presented in the form of the map. (Plate B, page 64.)

These two maps exhibit in a graphic way the broader facts of the uses of specific soils and groups of soils for the production of distinct crops and associations of crops.

The striking features of correspondence between the two maps are:

The sandy soils of the Lakewood series have been found to be too droughty for the common practices of crop production, and the greater part of their area remains in forest.

The undrained soils of the tide-marsh areas have been reclaimed only to a small extent, and they are chiefly unused or only occupied for the growing of forage crops or for pasturage.

The soils derived from the outcroppings of the marly deposits of Cretaceous and Eocene age are chiefly occupied for general farming purposes and to a limited degree for the growing of special crops. Only steep topography and excessive erosion interfere with complete occupation of the soils of the Collington and Colts Neck series, which are the chief soils derived from these deposits.

The soils derived from the later sediments which mantle a large area within the Raritan and Delaware Valleys and which occur as a terraced border around a large part of southern New Jersey are occupied almost to the limits of their occurrence for the growing of a wide variety of crops. The soils of this origin belong chiefly to the Sassafras series. Within this series the selection of particular soils for specific crop uses has proceeded further and has reached a greater degree of specialization than on any other group in the region.

In a general way the distribution of soil series and types in southern New Jersey is marked by zonal alignment and the distribution of dominant groups of crops follows that form.

Neither climatic differences, which are small, nor differences in distance to market, which are relatively slight but which occur, nor differences in local transportation facilities, which exist to a limited degree—*no one, nor all of these influences, has been sufficient to obscure the evident dependence of crop production upon the geographical distribution of soils suited to the growing of certain crops and unsuited to the growing of others.*

REVIEW OF SOIL USES BY SERIES, CLASSES, AND TYPES.

For the purposes of the production of the general farm crops—hay, corn, wheat, oats, and grass for pasture—the heavier loam soils are preferred. Their presence in dominant area invariably leads to the production of these crops in chief acreage. As a result, dairying, the sale of wheat, corn, and hay as cash crops, and the growing of one other sale crop, Irish potatoes, constitute the dependence of those farmers whose holdings include any large areas of the Sassafras loam, Sassafras fine sandy loam, Collington fine sandy loam, and Collington sandy loam.

For the growing of potatoes the heavier soils of the Sassafras and Collington series are especially well suited. Consequently, Irish potatoes are the most extensively grown sale crop within the general farming belt, and their extensive production stops sharply at the boundaries of definitely sandy soils. Only for early truck sales are such soils even as the Sassafras sandy loam used to any extent for potato production.

The other main group of soils, the sands and coarse sandy loams, is as distinctly avoided for general farming as the loamy soils are chosen. Wherever the more sandy but tillable soils are found, from Raritan Bay to the mouth of the Delaware, trucking as a distinct farm business has gained the preponderance. Within this group of soils specialization in cropping has gone to such an extent that the farmers of southern New Jersey have developed distinct preferences for definite soil types for the growing of specific crops. The following tabulation, derived chiefly from the results of the detailed soil surveys, will show what experience to the present time has proved to be the accepted crop adaptations of the more extensive trucking soils.

TABLE XIV.—*List of soils by series, groups, and types, showing uses.*

SASSAFRAS SERIES.

Soil group and type.	Truck crops.	General farm crops.	Fruit crops.
. Sand group:			
Sassafras coarse sand.	Sweet potatoes, asparagus		
Sassafras sand	*Sweet potatoes, asparagus, cantaloupes, tomatoes,*[1] melons, peppers, eggplant, peas, beans, cucumbers, sweet corn.	Corn, *alfalfa, rye*	*Peaches,* berries.
Sassafras loamy sand	*Sweet potatoes, asparagus, cantaloupes, tomatoes,*[1] *melons,* peppers, eggplant, peas, beans, sweet corn.	Corn, *alfalfa, rye, cowpeas.*	*Peaches,* pears, berries.
Sassafras fine sand	Sweet potatoes, asparagus, *tomatoes,*[1] *cantaloupes,* melons, peppers, cucumbers.	Corn, hay, rye	Do.
I. Sandy loam group:			
Sassafras coarse sandy loam.	*Sweet potatoes, tomatoes,*[1] peppers, cucumbers.	*Corn,* hay, *rye, alfalfa*	*Peaches, berries, grapes.*
Sassafras gravelly sandy loam.	*Potatoes, tomatoes,* cabbage, peppers.	*Corn,* hay, *rye,* wheat	*Peaches, pears, apples, cherries, grapes, berries.*
Sassafras sandy loam.	*Potatoes, tomatoes, cabbage, sweet corn, peas, beans.*	*Corn, hay, rye, wheat,* peas, oats, alfalfa.	Apples, pears, peaches, grapes.
II. Loam group:			
Sassafras fine sandy loam.	*Potatoes,* tomatoes for canning, *cabbage.*	*Corn, hay,* wheat, oats	Apples, pears.
Sassafras loam	*Potatoes,* tomatoes for canning, cabbage.	do.	Apples.

[1] Early truck crops.

TABLE XIV.—*List of soils by series, groups, and types, showing uses*—Continued.

Soil group and type.	Truck crops.	General farm crops.	Fruit crops.
COLLINGTON SERIES.			
Collington sand	*Asparagus*, sweet potatoes, tomatoes,[1] *cantaloupes*, melons.		
Collington loamy sand	*Asparagus*, *melons*, cantaloupes, tomatoes,[1] peppers, sweet potatoes.		
Collington sandy loam, deep phase.	*Asparagus*, *sweet potatoes*, *tomatoes*, cantaloupes, melons, eggplant.	Corn, rye, hay	
Collington sandy loam	*Potatoes*, *tomatoes*, peas, beans.	*Corn*, *hay*, *wheat*	*Peaches*, apples.
Collington fine sandy loam.	*Potatoes*, *tomatoes*, *cabbage*, sweet corn, peppers, asparagus.	*Corn*, *hay*, wheat	*Peaches*, *apples*, *pears*.
Collington loam	*Potatoes*, tomatoes	*Corn*, *hay*, *wheat*, alfalfa.	
Collington gravelly loam		*Pasture*	
Collington clay		Pasture, hay	
COLTS NECK SERIES.			
Colts Neck gravelly sand			Peaches.
Colts Neck loamy sand	*Asparagus*, *sweet potatoes*, *cantaloupes*, *melons*, *tomatoes*,[1] sweet corn.	Corn, *rye*	Do.
Colts Neck sandy loam	*Potatoes*, *tomatoes*,[1] asparagus, melons, *sweet corn*.	*Corn*, *hay*, wheat	*Peaches*, apples.
Colts Neck fine sandy loam.	*Potatoes*, tomatoes	do	Peaches, *apples*.
Colts Neck loam	*Potatoes*	*Corn*, *hay*, *wheat*.	Do.
KEYPORT SERIES.			
Keyport sandy loam	Peppers, tomatoes,[1] melons		Berries.
Keyport fine sandy loam.	Tomatoes,[1] peppers, cucumbers, melons.		Do.
Keyport loam	Peppers, tomatoes [1]	*Corn*, *hay*	
Keyport clay loam	do	Corn, *hay*	
SHREWSBURY SERIES.			
Shrewsbury sandy loam	*Potatoes*, *tomatoes*, peppers	*Corn*, *hay*, wheat	Berries.
Shrewsbury fine sandy loam.	*Potatoes*	*Corn*, hay	Apples, peaches.
Shrewsbury loam		*Corn*, *hay*	
Shrewsbury silt loam		*Hay*	
KEANSBURG SERIES.			
Keansburg sand	Tomatoes[1]	Corn	
Keansburg sandy loam.	Potatoes, tomatoes	*Corn*, hay	
Keansburg fine sandy loam.		*Hay*, *pasture*	
Keansburg loam	Potatoes, tomatoes	*Corn*, *hay*	
MISCELLANEOUS SOILS.			
Portsmouth sandy loam	*Peppers*, onions, *cabbage*	Corn, hay	Berries.
Hyde loamy sand			*Cranberries*.
Elkton loam	Potatoes, *cabbage*	*Hay*	
Freneau loam	Potatoes	Hay	
Lakewood sand	Asparagus		Dewberries.
Lakewood gravelly sandy loam	Tomatoes, peppers, sweet corn, potatoes.	Corn, hay	
Lakewood fine sand	Asparagus, cantaloupes, melons, peas, beans, cucumbers, tomatoes, peppers, eggplant, squash.		
Tidal marsh	Cabbage, onions	*Corn*, *hay*	

[1] Early truck crops.

NOTE.—Crops most extensively grown on each type are in italics.

Summarized on the basis of the texture of soils—that is, by classes of soils without reference to the soil series—the soil uses actually found in southern New Jersey are now presented:

Coarse sandy types.—Asparagus and sweet potatoes are the only crops grown in any large area.

Gravelly sand.—Forested or used to a limited extent for peaches.

Sand.—The most important early truck crop class. Preferred for asparagus, sweet potatoes, cantaloupes, early tomatoes, watermelons, peppers, eggplant, peas, and beans. Some sweet corn grown.

Loamy sand.—An early truck soil. Used for sweet potatoes, asparagus, cantaloupes, early tomatoes, peppers, peas, beans, and eggplant. Also for corn, rye, alfalfa, mixed hay, and peach orchards.

Fine sand.—A slightly later truck soil. Tomatoes, peppers, cantaloupes, cucumbers, some sweet potatoes, and asparagus. Corn, rye, and hay, peaches, bramble berries are grown.

All of these classes of soils have a far greater value for the production of early truck crops than for any other purpose, provided markets are available. In the latitude of New Jersey they mature crops at a time when other areas offer little competition. More loamy soils mature crops at a later date and sometimes suffer from severe competition with near-by localities slightly farther south.

Coarse sandy loam.—Nearly as early as the sandy types. Sweet potatoes, asparagus, early tomatoes, peppers, cucumbers, predominate. Fairly good crops of mixed hay, good crops of corn, and alfalfa are produced. Peaches, bramble berries, grapes are raised.

Gravelly sandy loam.—When not indurated in the subsoil, produces tomatoes, peppers, early Irish potatoes, early cabbage, corn, hay, and some wheat. Extensively used for peach, apple, pear, and cherry orchards and for plantations of berries and grapes.

Sandy loam.—Possesses the widest range of crop adaptations of any group, being fairly well suited to growing numerous truck crops and nearly all of the general farm crops. Potatoes, tomatoes, peppers, eggplant, cabbage, sweet corn, peas, beans, and even asparagus and watermelons are grown. It is an excellent corn and hay group. Alfalfa beginning to be grown. Fair crops of wheat and rye, and some oats are raised. Good fruit soil when well drained. Apples, pears, peaches, and berries thrive.

This group forms an intermediate set of soils which produces large yields of truck crops at a season usually slightly later than the sand group. The more retentive subsoils permit the growing of the general farm crops which require a longer growing season. The corn and alfalfa crops are particularly successful on soils of this group.

Fine sandy loam.—This class of soils falls naturally with the more loamy and later maturing soil types. Potatoes, tomatoes for canning, cabbage, and sweet corn are important special crops. The types produce good crops of corn, mixed hay, rye, wheat, oats, and cowpeas. Apples and pears do well.

Loam.—This class includes the best general farming soils in southern New Jersey. Potatoes are the chief cash crop, with tomatoes for canning becoming an important crop in some sections. Corn, mixed hay, wheat, and oats produce their largest yields upon soils of this group, particularly upon the Sassafras loam, which is of greater extent and importance than any other single soil in the region. Apples, pears, and cherries thrive at proper elevations.

The fine sandy loam and loam soils rank together in their crop adaptations in this general region. They form the basis for the production of the general farm crops, for dairying, for the most extensive production of potatoes, and of tomatoes for canning. They produce the larger part of the forage crops and a considerable preponderance of the potato crop in the southern part of the State.

Corn, wheat, hay, potatoes, and dairy products are the chief commodities sold from them.

Silt loam.—Represented by only one type of limited extent. On this, hay and pasture are the chief form of agricultural production. Cabbage and potatoes are grown to a limited extent.

Clay.—Sparingly represented in southern New Jersey and usually avoided for crop production. Hay and pasture are the chief uses.

Tidal marsh.—Of considerable extent but sparingly utilized. Chiefly in grass for pasturage or hay. Some small areas are tilled to corn. Limited areas are devoted to tomatoes and cabbage.

CONCLUSION.

(1) The geographic location of the southern New Jersey region is such that the largest markets for staple and special farm products on the continent lie within easy reach of even the most remote localities. (See fig. 2, p. 4.)

(2) Transportation by steam railroad, by electric railroad, by improved highways, and even by water routes is more completely established than in the majority of communities in the country. (See fig. 2.)

(3) Agriculture has been established for a period of 275 years in parts of the territory under discussion. It has been established over the arable soils of practically all of southern New Jersey for a period in excess of 200 years.

(4) The region has sufficient rainfall during the year and during the growing season for maturing all the most important staple and special crops suited to the latitude. The growing season between killing frosts is usually six months long. (See fig. 1, p. 3.)

(5) There are within the region no differences in elevation which seriously disturb the climatic conditions imposed by latitude. The presence of large bodies of water exerts an equalizing influence upon temperatures which is sensibly evident to a distance of 10 or 15 miles from the Atlantic coast and to a distance of 5 to 10 miles from Delaware River and Bay. (See fig. 3, p. 6.)

(6) The more than two centuries of agricultural development in the region have brought about a thorough comprehension of the fact that crops do not all thrive equally well upon all soils. There has been a constant tendency to adapt the cropping and the agricultural systems of the regions to local soil conditions in such a way that the most paying crops may be grown upon each soil of marked characteristics. (See pl. A, p. 16, and pl. 13, p. 64.)

(7) This selective cropping has resulted in:

(*a*) The avoidance of excessively drained soils, like those of the Lakewood series, for any agricultural use.

(*b*) A failure to utilize wet soils for any but the most extensive systems of cropping, such as the growing of grass for pasture and hay upon the Tidal marsh areas.

(*c*) The utilization of the more sandy soils, irrespective of their relative distance from market, for the growing of the early vegetables, commonly called truck crops.

(*d*) The use of intermediate types of soils, such as the sandy loams, for the growing of a wide variety of truck crops, general farm crops and, where altitude favors, of commercial orchard crops.

(*e*) A decided specialization toward the grain and grass crops upon the fine sandy loam and loam soils, with the more recent use of the loam soils for the growing of Irish potatoes and of tomatoes for canning purposes.

(*f*) The utilization of every reasonably level acre of good upland soil for crop production of some kind. (See detailed soil and crop maps.)

(*g*) The utilization of small areas of overflow or of undrained land for grazing purposes in connection with the special tillage of all upland areas.

(9) Other things being reasonably equal, the farmers of southern New Jersey have a very decided and well founded preference for the utilization of each specific soil type for the growing of the special crop or group of crops which is best suited to that soil. (See Table XIII, p. 66, and detailed soil and crop maps.)

(10). These crop uses are given in some detail for the most important soil types and soil classes which have been encountered in four detailed surveys made in southern New Jersey. The uses of certain of the soils are established by four detailed maps showing the soil types and the crops actually supported by them. These four soil and crop maps represent four distinct sets of soil conditions and of resultant crop production. They fairly represent the range of soil and crop conditions within the area.

(11) The conditions, as depicted by the several classes of maps, agree within reasonable limits with the opinions of nearly 1,000 farmers in the region who expressed their soil preference for specific crops. (See detailed soil and crop maps and Table XIII.)

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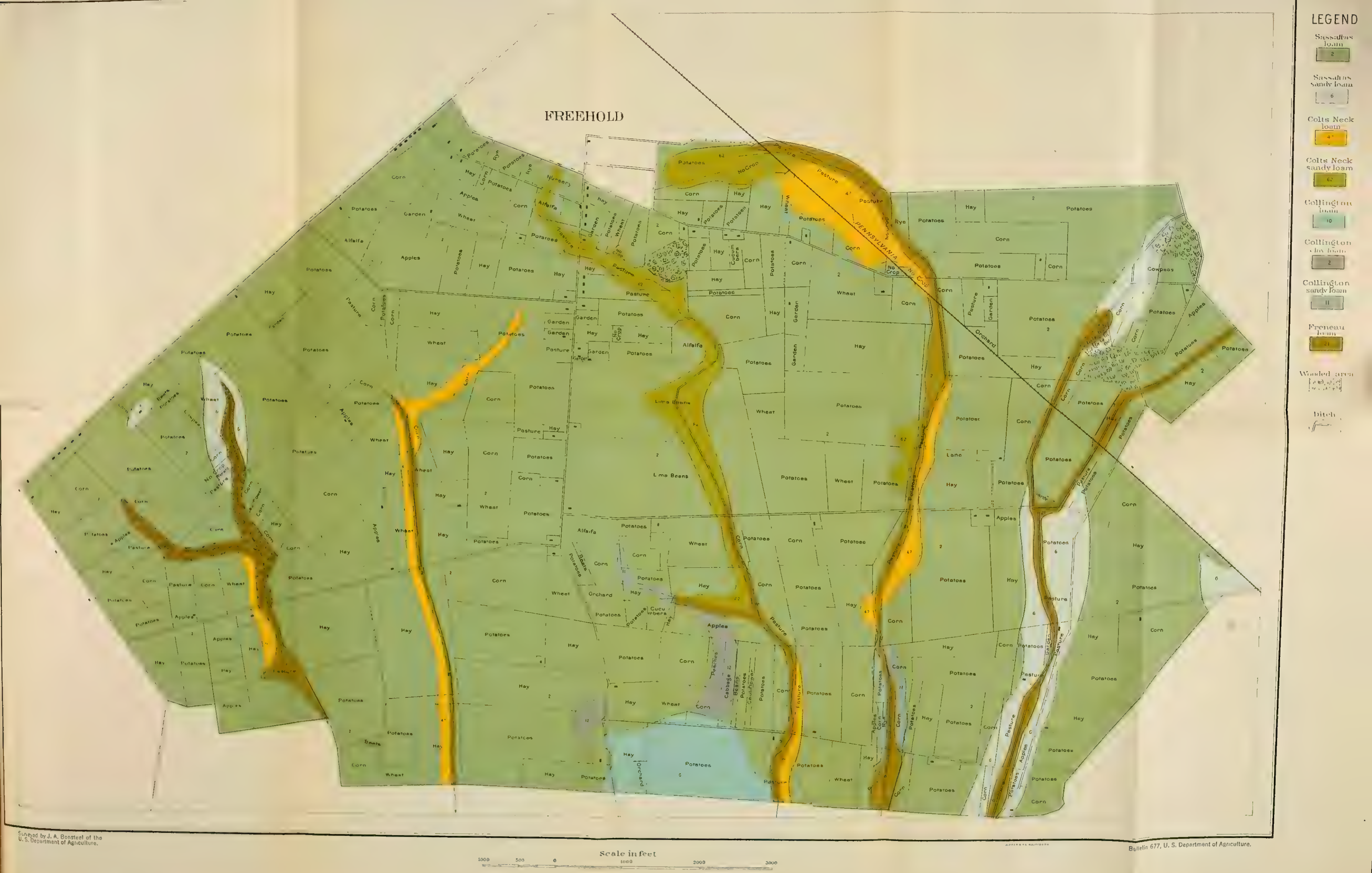
MILTON WHITNEY, CHIEF
CURTIS F MARBUT, IN CHARGE SOIL SURVEY

SOIL AND CROP MAP

NEW JERSEY
FREEHOLD SHEET



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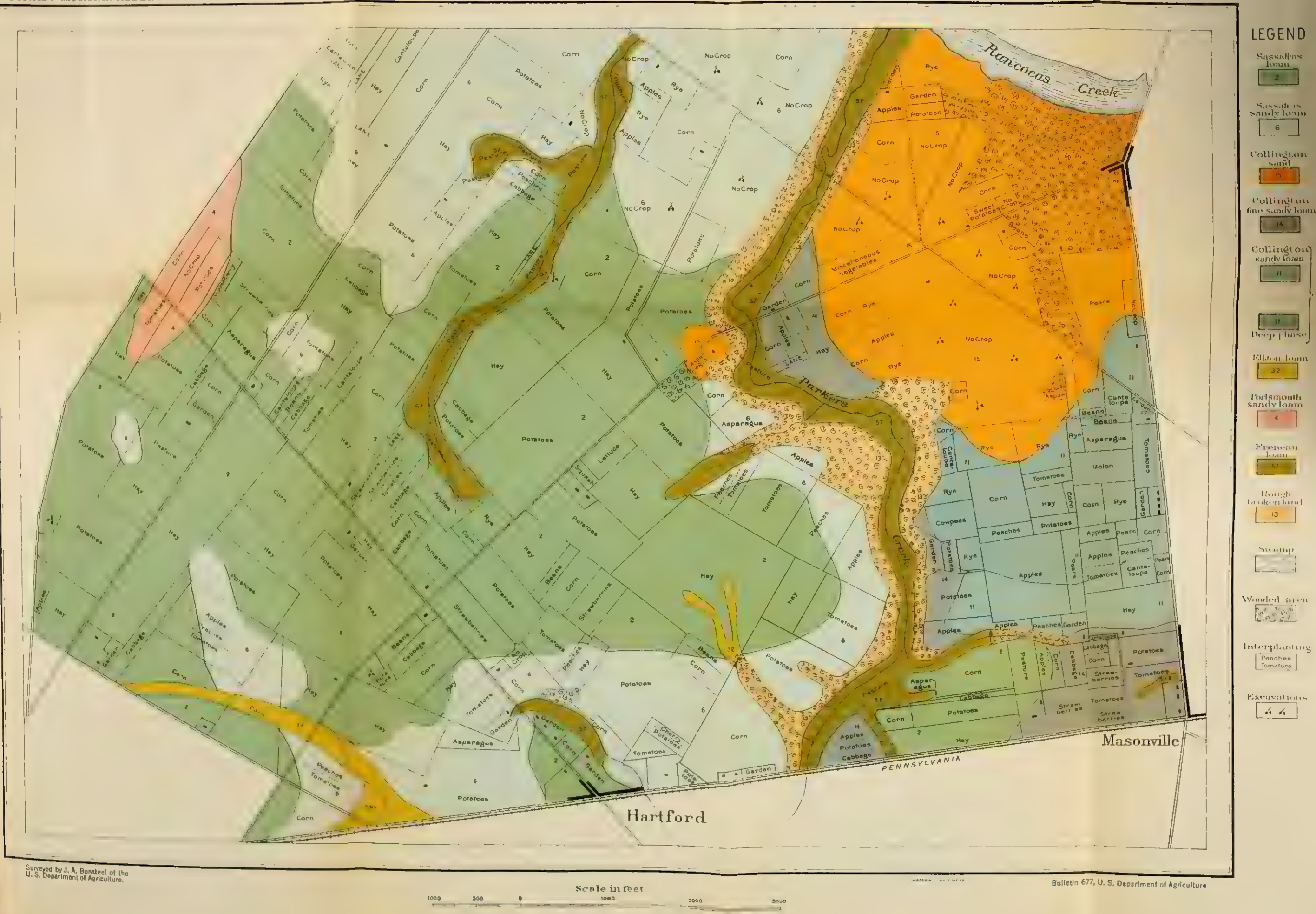
SOIL AND CROP MAP

NEW JERSEY
HARTFORD SHEET



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SOIL AND CROP MAP

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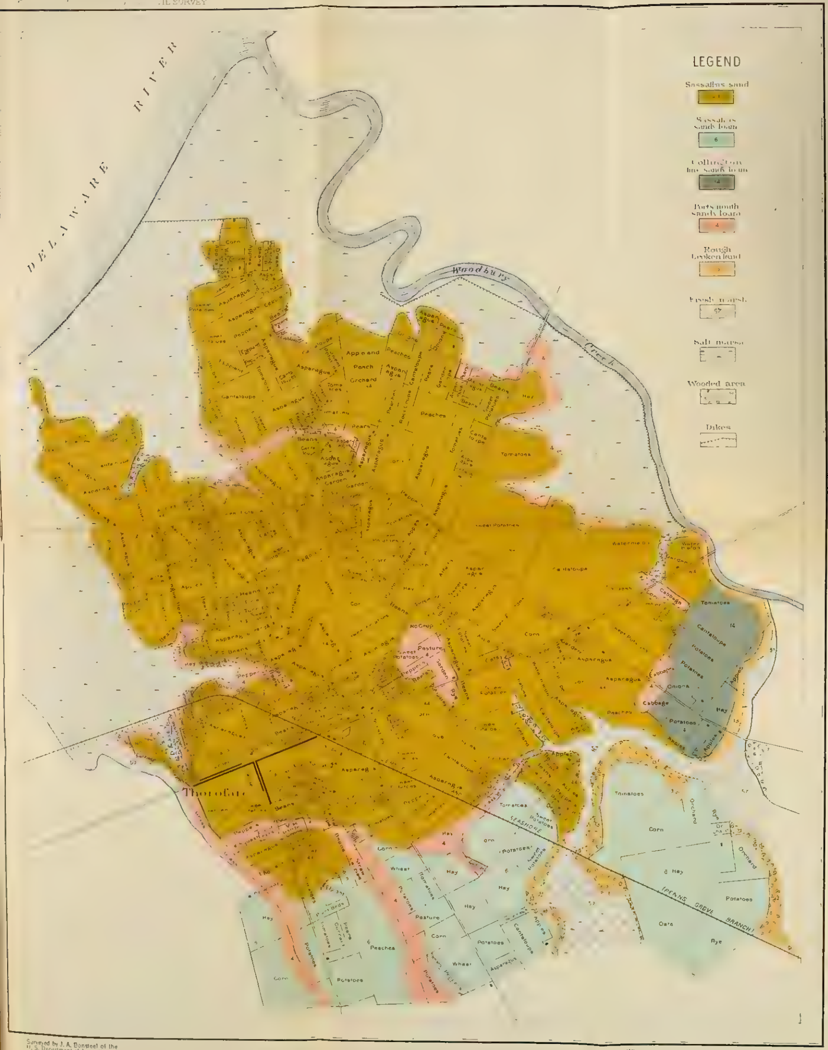

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Scale in feet

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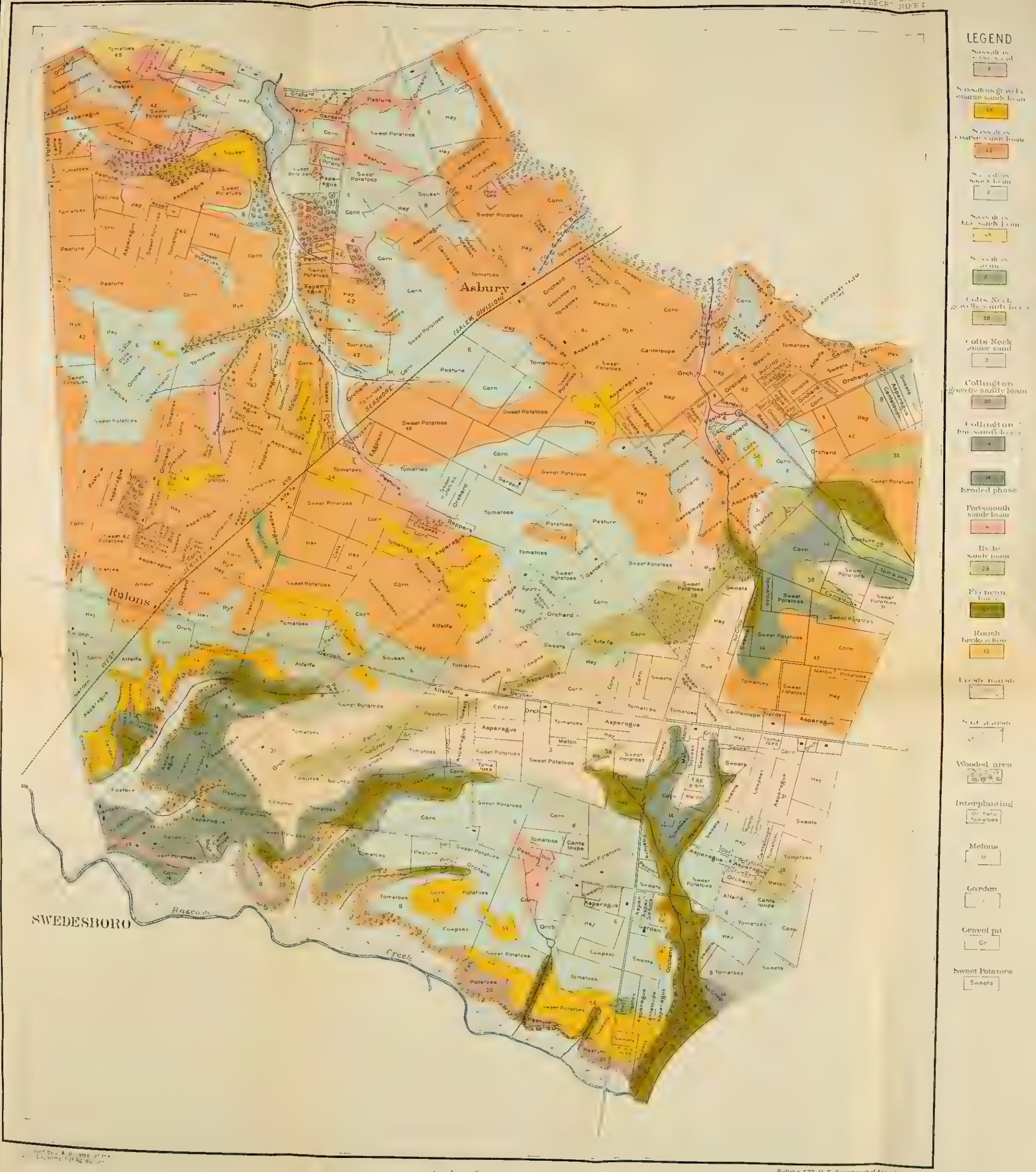
SOIL AND CROP MAP

NEW JERSEY
SWEDESBORO SHEET



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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 678

Office of the Secretary
Contribution from the Office of Farm Management
W. J. SPILLMAN, Chief

Washington, D. C. ▼ May 7, 1918

INFLUENCE OF A CITY ON FARMING.

[A study of types of farms and their organization in Jefferson County, Ky.]

By J. H. Arnold, *Agriculturist*, and Frank Montgomery, *Scientific Assistant.*

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OBJECT AND RESULTS.

This bulletin gives the results of a study of the agriculture of Jefferson County, Ky., a locality which is influenced greatly by a moderately large and growing city (Louisville). In response to a favorable and increasing market for vegetables, an increasing area of land is being utilized for trucking. The raising of such crops as potatoes and onions has been profitable, principally on account of exceptional marketing facilities. The raising of cereals, while still important, has declined. The city offers an expanding market for dairy products, but by means of railways and trolleys the city is quickly and cheaply reached by dairy farms located a long distance out, where cheaper land and other favorable conditions enable the farmer to compete successfully in the dairy market. With the growth of the city, the extension of trolley lines, and the improvement of highways, an increasing number of people occupied in the city are living in suburban towns and in the near-by country. All these factors combined create a set of conditions which bring about rapid changes in agricultural practice. Old types of farms once dominant are disappearing and new types are organized to profit by the opportunities offered. Farms that were once profitable as large units, under an extensive system of agriculture, come to be relatively unprofitable under new conditions creating higher values for real estate.

It is the purpose of this study to analyze these conditions in order to arrive at an understanding of the underlying principles of farm organization and practice here, to point out the more profitable types of farming, and to show how some of the more successful farms are organized.

The important conclusions drawn from this study are: (1) For the area surveyed the small farm intensively cultivated is the most efficient and profitable. (2) The most profitable types found are those specializing in potatoes and truck. (3) Dairying combined with truck farming is profitable here, but as a type it is gradually being pushed farther away from the city to cheaper land. (4) The general mixed type of farm, representing the extensive system and a high degree of diversity, is the least profitable in this area.

SOURCES OF INFORMATION AND BASIS OF STUDY.

In the fall of 1913 about 50 farms were visited in representative sections of Jefferson County. In this survey a detailed study was made of the leading crop enterprises, such as Irish potatoes, sweet potatoes, onions, a few other important truck crops, wheat, corn, orchard grass, timothy, and clover. Two produce exchanges were found successfully working in the county. A careful study was made of these. The city market was also made an object of study, as well as the wagon roads and trolley lines radiating from it into the farming community. In 1915 another farm-management survey was made of 100 farms in this area representing various types. These farms were located as shown by the dots in figure 1. In this survey a careful study was made of the organization and the business success of each farm.

Information relative to changes which have occurred in types of farming was obtained from the United States census statistics; Bureau of Crop Estimates, United States Department of Agriculture; and from direct observation and consultation with farmers in the region.

GENERAL CONDITIONS.

THE CITY AND THE COUNTY.

Jefferson County lies along the Ohio River where that stream has worn its channel through a low rim of mountains which form the western boundary of the Bluegrass Region. Thus it is a natural gateway for travel and transportation between much of eastern and central Kentucky and the western part of the State.

In the bend of the river below the Falls of the Ohio is the city of Louisville, occupying an area of about 28 square miles, with a population in 1916 of 267,342. Good macadam roads radiate from the city to various parts of the county. Along several of these highways trolley lines have been built, connecting small towns and suburban homes with the city. These, with several steam lines running out from the city, give the locality an excellent system of transportation. (See map, fig. 1.) Louisville is a large distributing center, with important machine factories and distilling and brewing establishments. There are minor establishments for canning vegetables and making pickles, sauerkraut, catsup, etc. These are important agriculturally, in that they give market gardeners a market for various surplus vegetables.

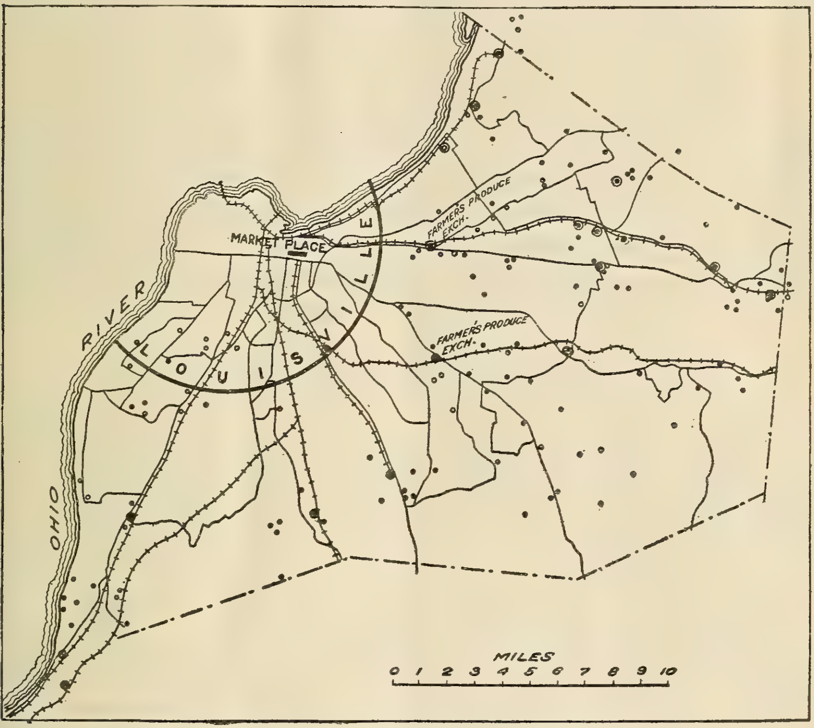

FIG. 1.—Map of area studied. Dots indicate farms visited.

The city market place is operated by an association of farmers and business men. The distance from Louisville to the farms included in this study is considered to be the distance from the market place to these farms. During the season of fresh vegetables and fruits this market place from early morning until noon each day is filled with vehicles of the truckers from the country. Here dealers and individual consumers come to buy the farmers' produce.

There are two important farmers' marketing and shipping establishments outside the city limits, one at St. Matthews and one at Buechel, both in localities where the Irish potato is the dominant enterprise.

POPULATION.

In 1910 the rural population of Jefferson County, including unincorporated towns, was 38,992, showing an increase of 42.4 per cent during the preceding ten years. During the same period the city population had increased 9.1 per cent. These figures indicate a rapid growth of suburban population. Outside of unincorporated towns, the increase was over 30 per cent. The increase in actual farm population was comparatively small, however—probably not over 10 per cent, since an increasing number of people who have occupations in the city are living in homes in the country. Seven per cent of the population in 1909 was foreign born and 32 per cent of mixed parentage. Much the larger part of the foreign population is German.

FACTS ABOUT FARMING SHOWN BY THE CENSUS OF 1900 AND OF 1910.

In 1909, according to the census figures, there were 3,093 farms in the county, an increase in ten years of about 9 per cent. During the previous decade the number of farms under 100 acres in size had increased 17 per cent, while farms over 100 acres in size had decreased about 14 per cent. During the same period the area devoted to the raising of vegetables had increased about 29 per cent, and the area devoted to cereals decreased about 22 per cent (see Table I).

TABLE I.—*Changes in crop production during the decade 1899–1909.*

Crop	1900 acreage.	1910 acreage.
Small fruits:		
Strawberries	818	443
Other berries	1,137	631
Total	1,955	1,074
Vegetables:		
Potatoes	6,525	9,255
Sweet potatoes	1,093	1,107
Other vegetables	5,787	6,920
Total	13,405	17,282
Cereals:		
Corn	33,316	31,200
Wheat	18,136	9,493
All cereals	55,672	43,280

Within the county, during the decade 1899 to 1909, there was a marked decrease in the production of market milk, while three adjoining counties farther out, with railway communications, had a marked increase in milk sold (see Table II). The decrease in Jefferson County was 43 per cent, while the increase in three outside counties was about 232 per cent. Jefferson county had a large increase in the amount of butter and cream sold, which to some extent made up for the loss in market-milk production. Butter, however, is made in small quantities as a by-product on nearly all types of farms, so that the increase in this product can not be said to make up the loss in market-milk production. The census figures further show a decrease in the number of dairy cows in Jefferson County and an increase in the three outside counties during the same period.

TABLE II.—*Changes in the dairy business during the decade 1899–1909.*

Area.	Milk sold.		Cream sold.		Butter sold.	
	1900	1910	1900	1910	1900	1910
	Gallons.	*Gallons.*	*Gallons.*	*Gallons.*	*Pounds.*	*Pounds.*
Jefferson County	2,695,233	1,542,455	5,757	24,342	239,926	528,915
Three counties outside of Jefferson in vicinity of Louisville	566,121	1,879,136	58,830	74,785	209,906	230,244

HISTORY OF IMPORTANT CROP AND STOCK ENTERPRISES SINCE 1840.

The figures of the United States Census Bureau relative to crops and live stock give a fairly good history of these enterprises since 1840. The high point of cereal production, characteristic of general mixed farming, was reached in 1870. Since then these crops have had a marked decline, while Irish potatoes, sweet potatoes, and other vegetables, characteristic of potato-truck and strictly truck farming, have had a corresponding increase (see Table III).

TABLE III.—*Statistics of crop production, 1840 to 1910.*

Year.	Corn.	Wheat.	Rye.	Barley.	Oats.	Hay.	Hemp.	Tobacco.	Irish potatoes.	Sweet potatoes.
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Tons.*	*Tons.*	*Pounds.*	*Bushels.*	*Bushels.*
1840	665,899	115,175	16,969	1,750	156,092	5,470	[a] 312½	75,360	[b] 60,604	....
1850	983,429	92,809	2,300	6,110	128,522	4,944	120	9,500	106,657	8,204
1860	974,110	155,785	12,352	45,305	134,029	9,543	204	13,560	177,963	31,854
1870	1,059,729	102,820	12,454	49,975	368,328	11,228	38	9,574	377,382	104,862
1880	1,056,209	186,212	10,413	21,643	114,793	11,186	....	11,632	269,066	99,307
1890	712,674	217,831	7,624	3,669	148,350	27,761	....	5,910	737,533	117,817
1900	1,003,130	239,880	3,030	....	91,570	[c] 27,589	....	132,840	887,640	150,832
1910	947,024	147,835	3,708	....	45,932	....	....	263,200	1,195,631	174,721

[a] Tons of hemp and flax. [b] Hay and forage. [c] Potatoes.

There have not been any significant changes in the total amount of live stock kept on the farm. Swine production fell off to a marked extent with the falling off of corn production. Dairy cattle reached their high mark in 1890 and 1900. Since then there has been a falling off in dairy production. (See Table IV.)

TABLE IV.—*Statistics of live stock, 1840 to 1910.*

Year.	Horses.	Sheep.	Swine.	Total cattle.	Milch cows.	Other cattle.	Working oxen.
1840	[a] 6,886	14,971	42,266	[b] 12,716	....	....	....
1850	4,893	10,798	39,573	7,987	4,338	3,220	429
1860	5,915	7,911	35,921	10,087	5,492	4,230	365
1870	6,360	7,089	34,575	9,334	6,263	2,957	114
1880	6,278	[c] 12,335	25,976	11,347	6,553	4,740	54
1890	7,820	7,463	16,932	13,250	8,565	4,664	21
1900	7,792	8,622	18,481	13,876	8,750	5,126	....
1910	7,062	7,411	13,700	11,129	7,594	3,535	....

[a] Includes mules. [b] Neat cattle. [c] Exclusive of spring lambs.

The history of crop yields since 1880 (see Table V) shows that for cereals the yield has been about stationary, while for intensive crops such as tobacco and potatoes the tendency seems to be toward an increased yield. Figures for determining the yields of the many different vegetables are not available. There is a tendency toward the increased use of commercial fertilizer, which is undoubtedly a factor in the increased yield of potatoes especially, and no doubt the yield of other vegetable crops has been increased thereby. The 1900 census gives the value of fertilizers used as $90,300, while that of 1910 gives $148,582. Besides commercial fertilizer, a large amount of stable manure is bought in Louisville and hauled to the truck farms.

TABLE V.—*Comparison of crop yields in Jefferson County, Ky., during 4 census years.*

Crop.	Yield per acre.			
	1880	1890	1900	1910
Corn........bushels..	27.3	31.2	30.1	30.4
Wheat........do....	12.9	16.8	13.2	15.6
Rye........do....	9.5	10.1	15.2	12.0
Barley........do....	23.7	18.5	....	....
Oats........do....	14.3	12.0	22.9	20.2
Hay........tons..	.7	1.0	1.2	1.1
Tobacco........pounds..	447.4	738.7	790.7	978.4
Irish potatoes........bushels..	(*a*)	157.2	136.0	238.3
Sweet potatoes........do....	118.7	143.3	138.0	157.8

a No data available.

SOIL AND CLIMATE.

No soil survey has been made of Jefferson county. The soil in the northeastern part of the county is a clay loam similar in character to the bluegrass soils farther east. While much of the soil in this portion of the county is fundamentally of limestone origin, there is a large mixture of river deposit, especially where the land is level. This deposit from the ancient overflow of the river has given the soil a dark color and a different texture from that of purely limestone origin.

Along the river south of Louisville there is a strip of land 15 to 20 miles in length and 1 to 7 miles in width which has more of the character of a sandy loam. This section is lower in elevation than the section east of the city and in some places is swampy. While it is productive and capable of maturing vegetables earlier than the heavy soils east, it has not been in as much demand for residence property. Thus the market value of land along the river and south of the city is lower in price than land of equivalent agricultural value toward the eastern portion of the county.

The southeastern part of the county has relatively the poorest quality of soil, besides a portion of it being hilly or mountainous.

Except where the low rim of mountains above mentioned enters the county, the topography is generally level. Much of the region might be termed river-bottom land.

The climate is typical of that found in the lower elevations of the south-central States (see figures 2 and 3). The winters are comparatively wet, the highest average rainfall coming in March. The dry season begins in July and ends in November. The average growing season extends from about the middle of April to a little past the middle of October, a period of about 186 days. During the year about 200 days are available for field work.

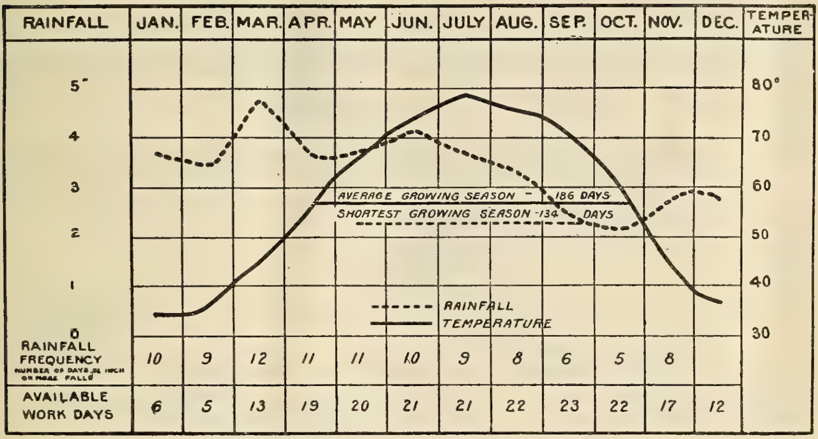

FIG. 2.—Diagram showing average climatic conditions.

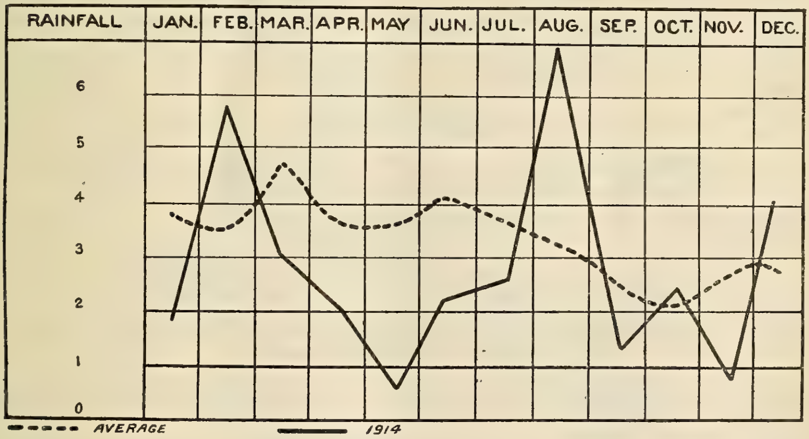

FIG. 3.—Diagram showing actual rainfall in 1914, with normal.

SEASONAL DISTRIBUTION OF LABOR REQUIRED BY CROPS.

The seasonal limits within which a crop is raised and marketed are determined largely by the climate. Long agricultural experience in a locality will result in the selection of such crops as are adapted to the natural and economic environment, and will establish a common practice in cultivating and harvesting them. Thus is developed a cropping system which is characteristic of the community. Figures 4 and 5 show the seasonal distribution of labor on the principal crops in this locality. Truck crops, of course, have an important relation to the cropping system here, but they are so numerous and the practice related to them so complicated that it was thought best not to give in this bulletin the seasonal distribution of labor on any of them except Irish potatoes, sweet potatoes, and onions, which have on farms a place more nearly equivalent to that of general field crops.

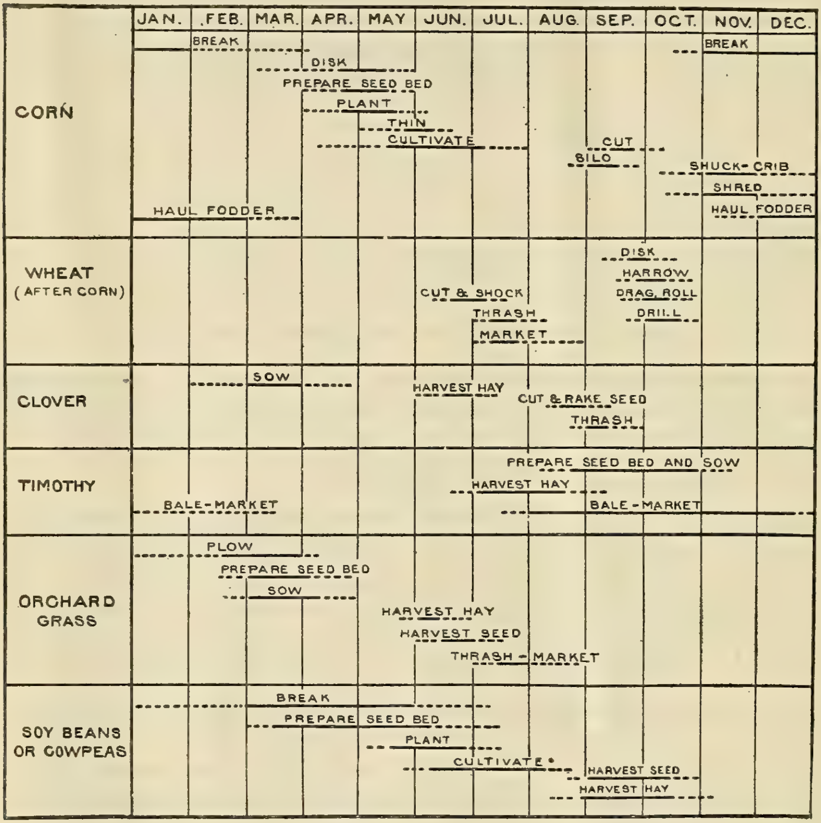

FIG. 4.—Diagram showing the seasonal work on general field crops. (Solid lines indicate average season; dotted lines extreme range.

The heavy lines show the limits of the average season for the operations required. The dotted lines show the variation in the practice of different farms or the variations on the same farm from year to year due to weather conditions. Charts of this kind have been used by individual farmers and found to be of considerable practical value, in that they help to form a mental picture of the seasonal labor requirement for the year.

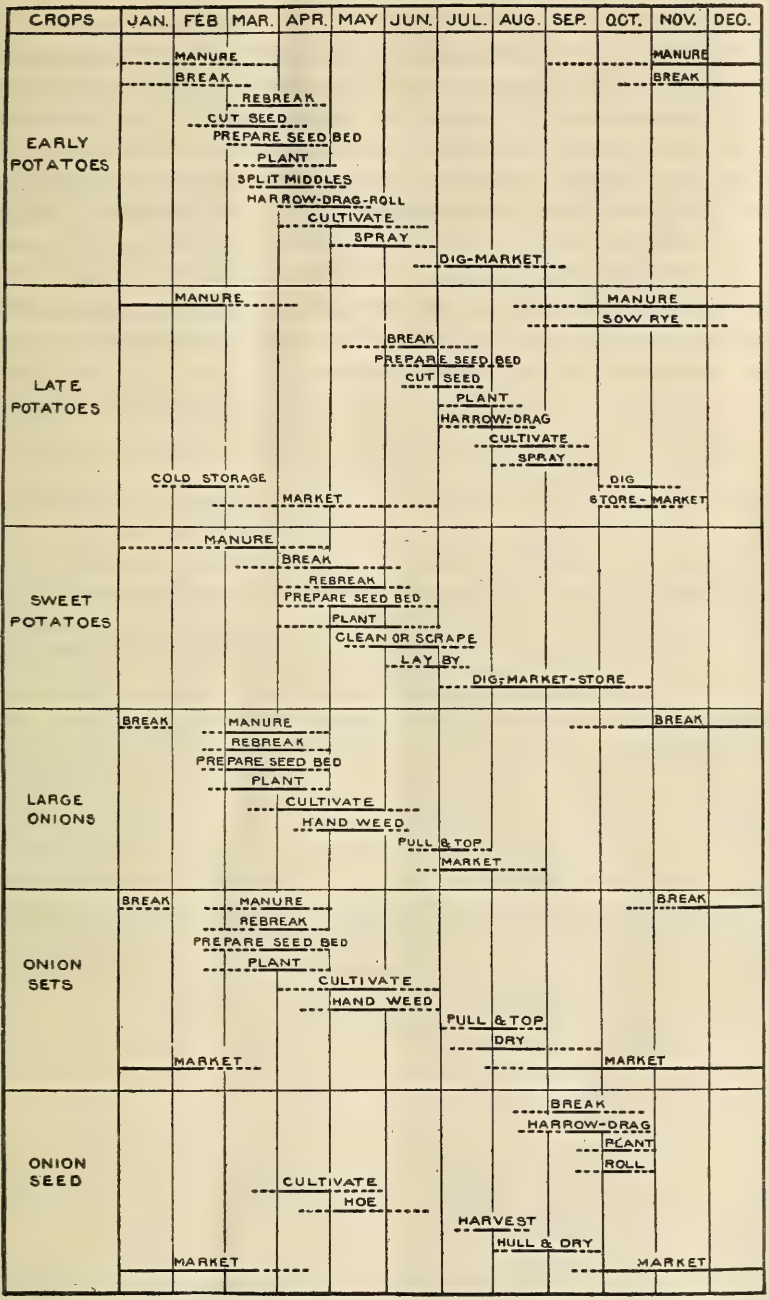

FIG. 5.—Diagram showing the seasonal work on potatoes and onions. (Solid lines indicate average season; dotted lines extreme range.)

DESCRIPTION OF FARM PRACTICE.

As will be shown in the following pages, several types of farming are found here, representing two general systems of farm practice, the extensive and the intensive. The farms practicing the extensive system are found toward the eastern part of the county and become more nearly typical as the bluegrass region is approached. These farms usually are large or medium-sized. The rougher and stony parts are kept in permanent bluegrass pasture. Orchard grass and clover are grown in rotation with grain and potatoes. Live-stock enterprises, dealing chiefly with beef cattle, dairy cows, sheep, swine, and horses, are important. Irish potatoes, which often take the place of corn as an intertilled crop on these general farms, commonly occupy 25 to 50 acres.

TABLE VI.—*Relative distance from market and size of farm to diversity and intensity of cultivation, illustrated by 17 farms.*

Farm No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Distance to Louisville (miles)	20	20	20	14	12	10	10	9	8	8	8	5	5	5	5	4	4
Size of farm (acres)	350	340	300	60	60	65	297	247	137	324	80	70	100	53	12½	130	35
Value of land per acre	$100	$100	$200	$100	$100	$100	$75	$100	$100	$200	$600	$300	$600	$700	$700	$500	$650
	Ac.	*Ac.*	*Ac.*	*Ac.*	*Ac.*	*Ac.*	*Ac.*	*Ac.*	*Ac.*	*Ac.*	*Ac.*	*Ac.*	*Ac.*	*Ac.*	*Ac.*	*Ac.*	*Ac.*
Potatoes, first	25		45	5	4	1½	18	15	10	32	30	35	11	20	4	40	25
Potatoes, second	8	50	5	10½	5	9	28	20	15	14		10	50	*a* 21			*a* 25
Sweet potatoes											9		13	10	2	12	
Cabbage											7	*a* 2	*a* 6	4	1½	*a* 10	4
Field onions									4		5		*a* 4	4	1	*a* 4	1½
Onion sets		4										*a* 1			1	*a* 8	3
Onion seed		23			1½								*a* 15				
Tomatoes				1½								*a* ½	4		1	3	
Roasting ears													*a* 10			10	
Lettuce													3	½		*a* 2	
Beets												*a* ¼			¾	3	
Asparagus											2		4			4	
Carrots													1	¼			
Rhubarb													1½		½	3	
Cauliflower											2	1				2	
Beans												*a* ¼	*a* 6				
Cucumbers												1				1	
Horse radish											1		2		½	4	
Parsnips											1	5	4				
Peppers				¼													
Spinach												*a* 6	*a* 2			1	
Melons					1	1							1½				
Cantaloupes					1½											5	
Strawberries		4			2	1											
Blackberries		3															
Cherries		1				1											
Grapes		4½															
Apples		6				7						5				5	
Pears						5											
Corn	50	22	27		11	20	50	45	20	19		12				12	
Wheat	100		80				100	52	50	120							
Oats	35		20	5	3	5				12		4					
Rye	*a* 30			*a* 30		*a* 10	*a* 20	*a* 20		*a* 15	*a* 5	*a* 15	*a* 13			10	
Clover	40	35	60	16						30							
Timothy			4	3	10		25	30	10	26	10	15	8				
Orchard grass	40				5					10							
Cowpeas	5	20	4	11					8	*a* 10							
Alfalfa		10									5		4			6	
Millet						3											
Soy beans	15		35														
Cane										1							
Crab grass									*a* 30	*a* 10							

a Double cropped.

On the smaller farms nearer the city the farm practice is entirely different. About all the tillable area of these farms is planted in field or truck crops, a very small percentage being left for pasture. Much of the land is double-cropped. These farms near the city are smaller in size than those 10 to 20 miles out. The size of the business conducted on many of them is large, however, owing to more intensive cultivation. These farms show greater diversity than the big farms, and the crops require much more labor and fertilizer per acre. These factors are well illustrated in Table VI.

The truck gardeners generally keep something growing on the land all the year. Kale and spinach are favorite winter crops. Some of the crop may be marketed in the late fall and early spring, and the remainder is turned under. Rye is commonly sown to be turned under for a late crop of potatoes.

RELATION OF DISTANCE FROM CITY TO TYPE OF FARMING.

The farm records taken were distributed as evenly as possible over the county and no thought was given to the selection of any particular type of farm. For this reason the farms at different distances from the city will represent fairly well average conditions. Mention should be made, however, of one factor which interferes to some extent with a study of farms grouped according to distance from the city. As previously stated, a strip of land extending 20 or more miles south along the Ohio River is almost wholly utilized for trucking, so that for this area the factor of soil has a predominating influence. Table VII would indicate, nevertheless, that distance from the city has an important influence on the type of farming. Truck crops (except as influenced by the factor just mentioned) and potatoes are dominant enterprises near the city. Receipts from such field crops as corn, wheat, hay, hogs, and stock cattle are grouped in the table under the head "Receipts, per cent, from other sources." These enterprises are characteristic of general mixed farming, and become more important as the distance from the city increases. Dairying also becomes more important as distance from the city increases.

TABLE VII.—*Relation of distance from city to type of farm.*

Distance from Louisville.	Number of records.	Size of farm.	Rent of land per acre.	Receipts, per cent.		
				From truck and potatoes.	From dairy.	From other sources.
8 miles or less	25	102	$11.85	68	10	22
9 to 11 miles	18	221	5.59	35	12	53
12 to 14 miles	24	256	5.37	34	20	46
15 miles and over	33	257	4.66	20	27	53
All farms	100	211	6.80	38	18	44

These facts relative to the type of farming have an important relation to the value of land and the size of farm, as is indicated also in this table. Farms increase in size and the rent per acre decreases as the distance from the city increases.

The lesson to be learned from these facts is that close proximity to a large growing city tends to make it more profitable to grow truck crops which can be marketed fresh to the consumers in the city than the staple crops characteristic of general farming and supplying a wide market. The nearer a location is to the city the more valuable the land becomes, because it is demanded for dwelling, factory, and transportation sites, etc., in competition with agriculture. On high-priced land none but intensive agriculture will pay. Because land is more valuable near the city, and since a large farm business may be conducted on a small piece of land, the farms tend to be smaller near the city.

Frequently a farmer owning a comparatively large tract of land, 300 to 400 acres, finds the city growing towards him, increasing year by year the value of his land. With this increase in value of land goes an increase in costs of production. Unless the farmer changes his type of farming to meet these conditions his business can not be made to yield interest on the increased capitalized value and a profit in addition. Under such conditions the farmer usually sells all or a part of his land to be divided into smaller tracts, either for dwelling and industrial sites or for smaller farms operated more intensively.

THE SMALL, INTENSIVE FARMS NEAR THE CITY ARE THE MOST PROFITABLE.

With intensive farming and higher production per acre the farmer is enabled to carry on a good-sized business on a small-sized farm. In fact, in this study no relation appeared between the size of the farm and the size of the business conducted. The capital invested in the average large farm did not differ materially from that invested in the small intensive farm. (See Table VIII.)

TABLE VIII.—*Relation of size of farm to operating expenses per acre and to land earnings per acre.*

Size of farm.	Number of farms.	Distance to Louisville.	Average area of improved land.	Operating expense per acre.	Gross receipts per acre.	Land earnings per acre.[a]	Labor income.	Profit on investment.
Acres.		*Miles.*	*Acres.*					*Per cent.*
Less than 80 [b]	21	9	44	$73	$96	$23	$1,000	7
80 to 159	25	12	121	36	45	9	800	5.6
160 to 299	33	13	212	15	20	5	100	4
300 and over	21	16	420	14	18	4	140	4
All farms	100	....	199	32	42	10	....	....

[a] Land earnings per acre as here used is what is left after paying all operating expenses, which include all current expenses, 6 per cent interest on working capital, and the farmer's estimate of the value of his labor and services as manager, amounting for the average farm to about $600. Land earnings would be then approximately what the landlord might expect as rent.

[b] Improved land.

According to Table VIII the average farmer with less than 80 acres spends $73 per acre in operating expenses and gets $96 per acre in gross receipts, thus making each acre earn, net, $23. On the other hand, the average of 21 farms over 300 acres in size expends in operating expenses $14 per acre and gets $18 per acre gross receipts, making each acre earn but $4. Among the farms represented in the table, the small, intensive farm is the more profitable, both from the standpoint of wages for the operator and from the standpoint of invested capital.

The average of 21 farms less than 80 acres in size gives the operator a labor income of $1,000 and 7 per cent on capital invested, while the average of 21 farms over 300 acres in size gives the operator a labor income of only $140 and 4 per cent on capital. The main reason for low profits on the larger as compared with smaller farms is that many of the larger farms are not doing intensive enough agriculture to meet the new conditions brought about by a large and growing city.

DISTANCE FROM THE CITY A FACTOR IN THE VALUE OF LAND.

As has been pointed out, the building of good roads, the extension of trolley lines, and the nearness of the city have made much of the land in this section desirable for other than agricultural use. Such conditions will naturally make the average market value of land higher than it should be for agricultural use alone. As would be naturally expected, the market value of land will tend to increase as the distance from the city becomes less. This is indicated in Table IX. Other conditions, such as soil and topography, however, may counteract the influence of the city.

TABLE IX.—*Influence of the nearness of the city on the value of land and rent.*

Distance to Louisville.	Number of farms.	Rent of land per acre.[a]	Value of land per acre.[a]
Less than 8 miles	25	$11.85	$312
9 to 11 miles	18	5.59	110
12 to 14 miles	24	5.37	106
Over 14 miles	33	4.66	95
All farms	100	6.80	158

[a] Farmers' estimates.

MANURE AVAILABLE IN THE CITY.

To some extent large quantities of stable manure are used by truck farmers in the vicinity of Louisville. This is usually bought in the city for from 50 cents to $1 per load, averaging about a ton in weight. Two farmers doing a large trucking business about 4 miles from the market place in the city each kept a man and team busy most of the year hauling manure. Very little is hauled more than 8 miles out. Of course some is shipped out beyond this distance on railroads and trolley lines. No doubt the availability of manure at a reasonable price is one of the limiting factors in profitable truck farming in the vicinity of the city.

Truck farmers customarily put the manure in large piles to rot. It is then hauled in small two-wheeled carts and scattered wherever it is wanted.

Table X illustrates the effect of land value and nearness to the city on the use of manure and commercial fertilizer. Besides these fertilizers, a considerable amount of green stuff, such as rye, clover, and kale, is turned under. These products are not included in the total cost of fertilizer. This table shows that the use of commercial fertilizer here is not as important a factor as in many other trucking sections. The land here, as a rule, is naturally fertile, and, as is evident, manure available in the city largely takes the place of commercial fertilizer.

TABLE X.—*The effect of land value and nearness to city on the use of manure and commercial fertilizer.*

Value of land per acre.	Number of records.	Distance to Louisville.	Size of farm.	Rent per crop acre.	Value of farm manure [a] and commercial fertilizer per crop acre.		
					Barn manure.	Commercial fertilizer.	Total.
		Miles.	*Acres.*				
Less than $80	23	16	284	$5.50	$3.75	$0.60	$4.35
$80 to $150	34	13	250	6.60	4.50	.70	5.20
$151 to $200	22	12	188	8.75	4.60	1.90	6.50
Over $200	21	8	95	15.00	18.00	1.25	19.25
All farms	100	12	212	8.60	7.35	.90	8.25

[a] The average value of manure is here estimated to be about $2 per ton load laid down on the farm.

A COMPARATIVE STUDY OF TYPES OF FARMS.

In the foregoing study of the influence of the city on farming, it is shown how there is a tendency for these farms to be smaller and more intensive near the city, while the farms 15 to 20 miles out are larger and raise general crops—corn, wheat, rye, bluegrass—and keep various kinds of live stock, such as beef cattle, dairy cows, sheep, and hogs. These enterprises are the sources of farm receipts, usually pretty well balanced between crops and live stock. Such farms may be classified as the "general mixed type." If dairying becomes a dominant enterprise, with 40 per cent or more of receipts from milk or milk products, the farm may be classified as a dairy farm. If 40 per cent or more of the receipts come from potatoes alone, the farm may be called a potato farm; if from potatoes and truck, a potato-truck farm.

These classifications are shown in Table XI. While farms of the different types differ greatly in the amount of land utilized, there is not so great a difference in the size of the business conducted. The capital invested and the expenses of operation furnish a good basis for comparing the size of business of each type.

TABLE XI.—*Relation of type of farm to size of business and labor income.*

Type of farm.	Number of records.	Acres of improved land.	Value of capital invested.	Total operating expenses per farm.	Labor income.
General mixed	39	270	$34,700	$3,667	$126
Dairy	22	205	27,782	3,686	441
Potato	11	192	35,000	3,715	333
Potato-truck	24	62	20,000	3,950	1,350
All farms	96	195	30,084	3,738	520

The potato-truck type of farming is by far the most profitable of the 4 groups. This fact undoubtedly accounts in large part for the tendency toward more intensive farming, as shown by a comparison of census statistics in 1900 and 1910. (See p. 4.)

It must not be concluded that the potato-truck farms grow only potatoes and truck, or that potato farms grow only potatoes. Other enterprises, such as corn, wheat, dairy cows, hogs, and sheep, have a place of more or less importance on most farms of these types. So also many dairy farms and general mixed farms handle enterprises characteristic of the more intensive types.

In the organization of the more profitable type of farms account must be taken of location with reference to the city, to soil, and transportation facilities. As the population of the city increases there will be a larger demand for farm products, including truck crops. The climate here allows the production of an early and a late crop of Irish potatoes each year. This condition, combined with excellent facilities for storing and marketing potatoes, makes possible the continued development of the potato-truck type of farming.

DISTRIBUTION OF CAPITAL ON FARMS OF DIFFERENT TYPES.

Table XII shows the amount and distribution of capital on the types of farms included in this study.[1] Potato-truck farms have the smallest investment both in real estate and in working capital. The investment in machinery and buildings is also lower than that of other types. The dairy farms have the least invested in cash to run the farm. In dairy farming money comes in at short intervals, so that comparatively little need be kept on hand to meet expenses.

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[1] Most of the farms that may be classified as strictly "truck farms" are south of the city along the Ohio River on the sandy loam soils. Because there is not much demand in this section for suburban residence property, and because there still remains a good deal of undeveloped and unoccupied land, prices here are relatively low. These facts partly account for the low capitalization of these truck farms.

On the other hand, in the potato type and general mixed type a much larger amount must be kept on hand to meet current expenses.

TABLE XII.—*Relation of type of farm to distribution of capital on 96 farms in Jefferson County, Ky.*

[Values are averages.]

Type of farm.	Number of records.	Total capital.	Market value of real estate.[a]	Working capital.[b]	Investment in live stock.[c]	Investment in machinery.	Cash to run farm.	Investment in work stock.	Value of dwelling.	Value of other buildings.
General mixed....	39	$34,700	$30,589	$4,111	$1,977	$722	$785	$1,050	$2,619	$1,626
Dairy.............	22	27,782	23,247	4,535	2,911	697	448	661	2,950	2,349
Potato............	11	35,000	31,406	3,594	1,358	769	1,100	923	3,545	2,002
Potato-truck......	24	20,000	17,511	2,489	847	620	698	697	2,062	946
All farms....	96	30,084	26,198	3,859	1,986	691	706	844	2,660	1,707

[a] Value of real estate includes value of dwellings and other buildings.
[b] Working capital includes feed and supplies, but these are not separately given in this table.
[c] Investment in live stock includes the value of work stock.

THE UTILIZATION OF LAND AREA.

The potato-truck and truck farms have about 80 to 90 per cent of their improved land area in crops and about 10 to 20 per cent in pasture. These two types of farms show a better utilization of improved land area than other types, from the fact that 10 to 30 per cent of their improved area is double cropped. A very small amount of double cropping is practiced on the more extensive types of farms. Table XIII shows the utilization of land area by types of farms.

TABLE XIII.—*Relation of type of farm to the utilization of land area.*

Type of farm.	Number of records.	Acres of improved land in farm.	Per cent improved land—		
			In crop area.	In pasture.	Double-cropped.
General mixed............................	39	270	70	29.7	1
Dairy....................................	22	205	48	51.6	4
Potato...................................	11	192	77	23.0	6
Potato-truck.............................	24	62	86	14.0	20
All farms............................	96	195	69	31.0	8

The pasture area on small and intensively cropped farms is usually the rougher portions of the farm along creeks and sometimes the stony and ill-drained parts. On the larger and more extensive types there is, besides the permanent pasture, pasture in rotation with other crops.

DISTRIBUTION OF CROP AREA.

Table XIV would indicate that about 50 per cent of the crop area on the average truck and potato-truck farms is used in growing truck and potatoes, crops which represent intensive farming. The remainder of the area is used for growing corn, hay, and miscellaneous crops, principally for feeding the work stock, dairy cows, and hogs. In the other type groups also a small percentage of the farm area is devoted to truck and potato crops, showing the importance of these as money crops and the tendency toward more intensive farming. The largest percentage of green manure crops are found on farms specializing in potatoes. The practice is usually to sow rye in the fall and turn it under during the latter part of May or early in June for a late crop of potatoes, which is usually planted during the first two weeks in July. Turning under the rye and keeping the ground in good tilth and well packed with a plank drag or roller serves to retain moisture, to store humus, and to make general soil conditions favorable for the potato crop.

TABLE XIV.—*The distribution of crop area on different types of farms.*

Type of farm.	Number of records.	Crop area in farm.	Per cent of crop area in—							
			Corn.	Silage.	Potatoes.	Wheat.	Meadow hay.	Truck.	Miscellaneous crops.	Green manure crops.
Potatoes	11	133	17.9	3.4	24.9	16.2	12.9	3.5	8.8	12.4
Potato-truck	12	60	15.2	....	29.6	1.2	12.2	24.1	8.2	9.5
Truck	12	45	16.6	....	13.1	1.3	12.7	39.9	13.5	2.9
Dairy	22	82	26.0	9.1	5.7	7.3	15.7	2.4	28.8	5.0
General mixed	39	160	27.2	.9	8.6	17.9	21.4	2.4	14.9	6.7

DISTRIBUTION OF ANIMALS.

Table XV shows the distribution of different classes of animals on the different types of farms. On the intensive types, dairy cows, poultry, and swine are comparatively more important, while on the more extensive types, stock cattle, horses, and sheep are relatively more important. On the more intensive types of farms growing potatoes and truck, there is relatively a large amount of unmarketable products which, without stock to utilize them, would be wasted. Dairy cows, swine, and poultry utilize these as well as the permanent pasture, and thus are profitable when in proper proportion to other enterprises.

TABLE XV.—*Distribution of animals on farms of different types in Jefferson County, Ky.*

Type of farm.	Number of records.	Number of animal[a] units.	Distribution of live stock.						
			Dairy cows.	Young stock.	Steers.	Work stock raised for sale.	Sheep.	Swine.	Poultry.
			P. cent	*P. cent.*	*P. cent.*	*P. cent.*	*P. cent.*	*P. cent.*	*P. cent.*
Potato	11	12.0	30.8	13.0	12.0	1.4	2.0	23.4	17.4
Potato-truck	12	5.9	37.7	8.0	....	.4	....	37.7	16.3
Truck	12	5.1	29.9	14.5	....	....	....	24.6	31.0
Dairy	22	40.3	62.1	13.5	2.0	3.5	4.7	9.9	4.4
General mixed	39	23.1	22.0	10.3	13.1	3.1	8.9	32.8	9.5

[a] An animal unit is the equivalent of a cow, horse, or mule. Four calves, 2 yearlings, 5 hogs, 7 sheep, or 100 head of poultry are assumed to be approximately equivalent to an animal unit. The assumption is that each of these equivalents consumes about the same amount of feed and produces about the same amount of manure measured in terms of fertilizer value.

DESCRIPTIONS OF SEVERAL FARMS ILLUSTRATING TYPES FOUND IN THIS SECTION.

In the following pages are given descriptions and summaries of the 1914 (farm year 1914–15) business of several farms, which illustrate the various types found in this section. The comments made on the organization and success of each of these farms will be better understood if the average yield of various crops and the amount of labor required to produce them are given. (See Table XVI.) These figures will also be of great practical value in estimating the total amount of man and horse labor required in growing any of these crops, as well as the total yield which may be expected under average conditions.

The farms which have been selected are among the more successful ones, and for this reason may furnish suggestions for good farm organization in this locality.

TABLE XVI.—*Estimated 5-year average crop yields per acre, and the amount of man labor and horse labor per acre required for important crops on certain farms in Jefferson County, Ky.*

Farm product.	Number of records.	Unit of yield.	Estimated 5-year average yield.	Labor required per acre or animal unit.	
				Ten-hour man-days.	Ten-hour horse-days.
				Per acre.	*Per acre.*
Corn	25	Bushels	34	3.4	3.7
Potatoes	32	Barrels	55	7.4	8.2
Wheat	25	Bushels	21	1.4	2.2
Rye:					
Thrashed	25	do	17	1.5	2.5
Cut and fed	25	Tons	0.9	1.1	1.8
Pastured	25			.2	.6
Oats:					
Thrashed	25	Bushels	31.4	1.3	1.7
Fed in bundle	25	Tons	1.1	1.3	2.0
Meadow hay	25	do	1.0	1.1	.7
Orchard grass seed	4			1.0	.7
Cowpeas and sorghum	4	Tons	1.5	1.7	2.7
Millet	4	do	1.6	1.7	2.7
Sorghum	4	do	4.6	2.0	3.0
Alfalfa	1	do	2.4	3.4	2.5
Sweet potatoes	7	Barrels	78	18.5	10.0
Large onions	10	do	57	28.1	12.4
Cabbage	7	Crates	161	18.2	9.2
Tomatoes	7	Bushels	175	26.4	14.7
Kale	3			3.7	3.4
Beets	3	Bunches	4,133	100.0	9.0
Snap beans	2	Bushels	74	11.0	7.0
Cantaloupes	3	Crates	143	10.0	8.0
Blackberries	3	do	88.7	78.0	14.0
Strawberries	6	do	101	30.0	10.0
Roasting ears	6	Barrels	32	6.5	6.8
				Per A.U.	*Per A.U.*
Cows on retail milk farms	10			21.3	7.3
Cows and young stock, general farming	16			12.6	1.7
Steers	12			3.0	2.5
Hogs	14			6.3	1.0
Sheep	14			3.6	.1

FARM 1.—A 60-ACRE TRUCK FARM.

Farm 1 is located about 12 miles from Louisville on a clay loam soil below the average in quality, the value being only $100 per acre.

The following is a statement of the business for the year 1914.

Total capital	$8,500
Working capital	2,534
Total receipts	3,550
Total expenses	653
Receipts from potatoes	735
Receipts from truck	1,988
Labor income	2,300

The crops sold were as follows:

Early potatoes, 4 acres	$180
Late potatoes, 5 acres	555
Strawberries, 2 acres	330
Onion seed, ½ acre	90
Large onions, 1 acre	480
Cantaloupes, 1½ acres	338
Melons, 1 acre	100
Tomatoes, 1 acre	250
Grapes, 2 acres	200
Garden sales, 1 acre	200

This farm bought no manure from the city, being too far away, but $87 was paid out for commercial fertilizer. There were 5 cows, bringing in $461, 2 head of young stock, 12 hogs, 200 chickens, and 3 horses. Twenty-two per cent of the receipts were from live stock.

This farm raised 11 acres of corn and 10 acres of hay, both crops yielding well, so that only a small amount of feed was bought—$81 worth. Crop yields were about 15 per cent above the average for the farms studied, and 78 per cent of the total receipts were realized from crops sold.

FARM 2.—130-ACRE POTATO-TRUCK FARM.

Farm 2 represents not only a large, but an exceptionally profitable business. It is located near the city limits, has a sandy loam soil, and is level in topography. The operator owned 40 acres and rented 90 acres for $500 cash. The land is valued at $400 per acre.

The business for the year 1914 showed—

Total capital	[1] $21,000
Working capital	5,000
Total receipts	18,500
Total expenses	7,600
Receipts from potatoes	8,370
Receipts from truck	9,728
Labor income	9,900

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[1] The value of rented land is not included in this figure.

During the year over 2,000 tons of manure, easily accessible, was bought. One hundred and twenty acres were utilized for crops, 6 acres for pasture, and the remainder was idle and waste land. Sixty-six acres were double-cropped, showing intensive use of the land.

Following is a list of crops yielding income:

Roasting ears, 16 acres	$620
Tomatoes, 3 acres	180
Asparagus, 4 acres	700
Spinach, 1 acre	100
Early potatoes, 35 acres	6,125
Late potatoes, 40 acres	2,250
Beets, 3 acres	300
Cauliflower, 2 acres	450
Early crop cabbage, 6 acres	150
Late crop cabbage, 4 acres	120
Cantaloupes, 5 acres	500
Early crop lettuce, 2 acres	400
Late crop lettuce, 2 acres	400
Large onions, 4 acres	640
Onion sets, 8 acres	2,118
Sweet potatoes, 12 acres	900
Lettuce in hotbeds, 1 acre	800
Horseradish, 4 acres	800
Rubarb, 3 acres	450
Sales from greenhouse	500

Ninety-seven per cent of the receipts were from these crops.

The animals kept on the farm were 11 work animals, 2 cows, 16 hogs, and 15 chickens.

It has been remarked that 90 acres were rented for $500, an extremely low rent for land so near the city and of such quality. This land was held for residence property and tenure was uncertain. Opportunities to rent such land at this price are very rare. Usually it rents for from $20 to $25 per acre.

The largest item of expense was for labor, the total cost being $4,150.

The unusually large profits secured from this farm were due partly to the unusually high price obtained for first-crop potatoes, which on account of drought during the growing season were practically a failure, except on the sandy loam soils well supplied with manure. There was a shortage in the local market, so that farmers who had potatoes coming on early obtained from $4 to $6 per barrel for them, the more usual price being $1 to $2 per barrel. Another important factor in securing these profits was good judgment in the selection and marketing of crops. This ability is gained only by long experience in such a business. Crop yields on this farm were only about 3 per cent above the average.

It may be pointed out further that this farmer was able to handle an unusually large business, one of the most important factors in the size of profits.

FARM 3.—A 30-ACRE POTATO-TRUCK FARM.

Farm 3 illustrates the possibilities of farming on high-priced land where a good market is available. This land was valued at $800 per acre. Twenty-seven acres were utilized for crops, all but 2 acres in truck and potatoes. These 2 acres were in meadow. Two acres of rye were sown and turned under for second-crop potatoes. The rye was also pastured to some extent in the winter. Three acres were counted as waste land.

The money crops were:

Asparagus, one-half acre	$100
Cabbage, 3 acres	302
First crop lettuce, one-eighth acre	300
Second crop lettuce, one-half acre	690
Large onions, 1 acre	258
Onion sets, 1½ acres	50
Peppers, 2 acres	252
Early crop potatoes, 2½ acres	706
Second crop potatoes, 7 acres	1,530
Sweet potatoes, 6 acres	1,270
Spinach, 1 acre	490
Miscellaneous vegetables	52

Practically all of the receipts were from truck crops and potatoes, which in the case of this farm were sold principally on the local market, and so may be regarded as one of the truck crops. It is noticeable that there was a fair crop of early potatoes, which were marketed at $3.50 per barrel, while the late crop brought only $1.60 per barrel. Crop yields were 38 per cent above the average.

There were 8 work animals, a few hogs and chickens, and no cows. Feed was a large item of expense ($700), only a little being raised on the farm. Two acres of meadow produced only 1 ton of hay. Two hundred and ninety-five dollars were spent for manure and $90 for commercial fertilizer. In all $1,360 was spent for labor, of which $720 was regarded as family labor. There were 8 in the family.

The following is a statement of the business for the year 1914:

Total capital	$28,750
Working capital	4,750
Total receipts	6,000
Total expenses	3,146
Receipts from potatoes, early crop	706
Receipts from potatoes, late crop	1,530
Receipts from truck	3,764
Labor income	1,179

FARM 4.—A 58-ACRE POTATO-TRUCK FARM.

Farm 4 is one of the smaller-sized potato-truck farms, located about 8 miles from Louisville and about 2 miles from a market where is located a farmers' exchange. The land was valued at $155 per acre. It shows a fairly successful business.

Total capital	$11,840
Working capital	2,840
Total receipts	3,000
Total expenses	1,590
Receipts from potatoes	2,195
Receipts from truck	660
Labor income	830

The income from crops was distributed as follows:

Early-crop potatoes, 6 acres	$600
Late-crop potatoes, 6 acres	1,595
Sweet potatoes, 2 acres	240
Cabbage, 2 acres	220
Strawberries,1 acre	200

Practically the entire income was from these crops, the yields of which were 12 per cent above the average.

The animals on this farm were 1 cow, with calf, 5 work animals, 5 hogs, and 100 chickens.

Besides the truck crops listed there were 12 acres of corn yielding 400 bushels, and 1½ acres of timothy. Two acres were in pasture. Only $35 was spent for feed. Fifty dollars was spent for manure and $125 for commercial fertilizer. The hauling distance, 8 miles, made stable manure more expensive than on farms nearer the city.

FARM 5.—A 340-ACRE POTATO FARM.

Farm 5, located about 10 miles from Louisville, is comparatively large in size. The quality of the land is below the average. Much of it is rolling and nearly 50 per cent of the area is in permanent pasture. It is valued at $80 per acre. A year's business showed:

Total capital	$33,000
Working capital	5,800
Total receipts	6,900
Total expenses	3,880
Receipts from potatoes	4,800
Receipts from truck and fruit	1,133
Labor income	1,365

The crops were:

Late potatoes, 50 acres	$4,800
Onion seed, 3 acres	370
Strawberries, 4 acres	225
Field crops, 4½ acres	150
Blackberries, 3 acres	150
Peaches and apples, 6 acres	150
Cherries, 1 acre	88

About 83 per cent of the receipts were from crops, the remainder from live stock.

There were 4 cows, 6 young stock, 4 horses 10 mules, 20 head of beef cattle, and 250 chickens on this farm.

Crop yields were about 3 per cent above the average.

On farms growing a large acreage of potatoes more work stock is kept than can be employed profitably throughout the year. This farm sold 4 mules after the potato crop was planted. When located near the city, the farmer may profitably employ work stock in hauling manure, and sometimes in public work, such as building roads, etc. On the whole, the stock enterprise is badly managed, since only a total of about $900 was received from this source, and yet these animals consumed produce from more than one-half the farm area and in addition $300 was spent for feed.

The labor bill on this farm was $1,900. One hundred dollars went for manure and $700 for commercial fertilizer.

FARM 6.—A 590-ACRE GENERAL MIXED FARM.

Farm 6 is a large farm valued at $42 per acre and located about 20 miles from Louisville. It is organized as a general mixed farm on which practically one-half of the receipts are from live stock.

The business for 1914 showed:

Total capital	$29, 476
Working capital	4, 400
Animal units	50
Total receipts	5, 400
Total expenses	1, 900
Receipts from live stock	1, 670
Labor income	2, 000

The income from crops sold was as follows:

Corn, 125 acres	863
Wheat, 50 acres	950
Stover	20
Straw	200
Alfalfa, 25 acres	240
Timothy, 60 acres	270
Tobacco	120

The live stock on this farm were 4 cows, 3 head of young stock, 137 sheep, 30 hogs, 9 horses and mules, and 5 colts. All these enterprises yielded some income, sheep yielding the highest.

About 160 acres were devoted to permanent pasture and 150 acres were in woods, from which there was no income.

Fifty acres of corn and 2 acres of tobacco were raised by a cropper, who got one-half of the crop. Crop yields were only 68 per cent of the average, and receipts per animal unit 89 per cent of the average.

One wage hand was hired for the year, and $700 was spent for extra labor. No commercial fertilizer or manure was bought. Two hundred and sixty-three acres devoted to field crops were generally level, the remainder being hilly and much of it in woods. On the whole this was a well-organized business for the kind of land and location.

FARM 7.—A 50-ACRE DAIRY FARM.

Farm 7 illustrates a well-organized dairy business on a small-sized farm. The location is 6 miles from Louisville. The land is of good quality and is valued at $350 per acre. Crop yields were 55 per cent above the average. Ten acres were in pasture. The business showed:

Total capital	[1]$15,300
Working capital	5,300
Number of cows	48
Total receipts	8,700
Total expenses	4,200
Receipts from dairy	7,700
Receipts from truck and potatoes	375
Labor income	3,700

The crops were—

Corn, 10 acres	400 bushels.
Potatoes, 5 acres	150 barrels.
Oats, 12 acres	36 tons.
Timothy, 6 acres	10 tons.
Sorghum and cane (soiling crops)	5 acres.
Onions	½ acre.

Feed bought cost $2,000, of which $1,800 was for bran and cottonseed meal.

This farmer owned 25 acres and rented 25 acres additional for $450 cash. The labor cost was about $1,300. Two regular hands were employed and $300 represented family labor.

An excellent quality of business is shown by the fact that receipts per cow were $160. About 26,000 gallons of milk were sold at an average price of nearly 28 cents per gallon.

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[1] This includes the value of the owner's land only.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 679

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

Washington, D. C. PROFESSIONAL PAPER May 20, 1918

THE APPLICATION OF OPTICAL METHODS OF IDENTIFICATION TO ALKALOIDS AND OTHER ORGANIC COMPOUNDS.

By EDGAR T. WHERRY, *Crystallographer.*

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OPTICAL PROPERTIES IN THE IDENTIFICATION OF SYNTHETIC CRYSTALLINE SUBSTANCES.

Because crystals are best developed among minerals and were first studied in that connection, the sciences of crystallography and mineralogy have grown up in close association, and most of the printed information on crystallography is to be found in the literature dealing with mineralogy. Optical crystallography has been evolved largely for the identification of minerals, especially as they occur in rocks or as they are produced synthetically. To be sure, the crystallographic constants and partial optical data have been measured on a large number of artificial substances, both organic and inorganic, but little use has thus far been made of these observations for determinative purposes. Although microchemical methods of identification are used in a number of fields, the recorded data are largely qualitative. For instance, a given substance, when treated with an appropriate reagent, yields "radiating needles," "stout prisms," etc., numerical, quantitative observations being made only exceptionally.

"A careful study of much that has been written, and especially of the illustrations that have been made, of microcrystals in plants and drugs shows that erroneous conclusions may be easily drawn from the general appearance of crystalline precipitates or aggregates of crystals that are formed."[1] When it is considered how greatly crystal habit may be modified by the conditions of formation, the presence of impurities in the solutions, etc., the desirability of such quantitative data is apparent.[2]

A number of crystalline alkaloids, when obtained in a pure or nearly pure state, can be fairly well recognized by certain microchemical and color reactions. When mixed, however, and particularly when small amounts of one acccompany large amounts of another, it is difficult to establish the presence and identity of each. As there seemed every reason to hope that optical-crystallographic measurements would furnish a ready and certain means for the recognition of these substances, even when mixed in widely divergent proportions, a series of observations was made by the methods outlined in this bulletin. The results were satisfactory.[3]

METHODS FOR DETERMINATION OF OPTICAL CONSTANTS.

APPARATUS.

The instrument known as the petrographic microscope, because it was developed for use in the science of petrography, the study of rocks, is really an apparatus for the accurate measurement of crystallographic and optical constants of crystals in general. For instance, the system to which a crystal belongs, the axial ratios of the substance, the refractive indices, double refraction, and optical axial relations can be ascertained by its use. The determination of several such features on the same crystal will naturally be of enormously greater diagnostic value than the mere recording of more or less accidental shapes assumed by a crystalline substance under ill-defined conditions, which is all that is usually done. Moreover, it is not necessary that large or well-developed crystals be available. Most of the data can be readily measured on crystalline grains 0.025 millimeter ($\frac{1}{1000}$ inch) in diameter, and in favorable cases on even smaller ones, down to 0.01 millimeter ($\frac{1}{2500}$ inch), or, in other words, on what would ordinarily be classed as finely powdered materials.

While for the complete study and characterization of a crystallized substance a somewhat elaborate microscope outfit is necessary, comparatively few unusual accessories are needed to apply the methods herein described to the identification of alkaloids. The microscope must be equipped with nicol prisms which can be adjusted so that their vibration planes are exactly horizontal (right and left) and vertical (forward and backward); and an eyepiece with cross hairs in corresponding positions must then be used. It is a great convenience if one of these prisms can be rapidly inserted and withdrawn without changing the position of its vibration plane. A revolving stage, an Abbe condenser, and a substage iris diaphragm are necessary. One 4-millimeter ($\frac{1}{6}$-inch) and one 8-millimeter ($\frac{1}{3}$-inch) or 16-millimeter ($\frac{2}{3}$-inch) objective are adequate for every purpose. A slot should be cut in the microscope tube between the top of the objective and the bottom of the upper nicol prism for the insertion of a selenite plate yielding the "sensitive tint," red-violet of the first order. This plate, which may be purchased from any dealer in petrographic microscopes, is inserted so that its direction *c* lies at 45° from the vibration planes of the nicols. Finally, liquids of known refractive index are needed, directions for preparing which are given on page 4.

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[1] Kraemer, Henry. Applied and Economic Botany (Philadelphia, 1914), p. 768.

[2] Fry, W. H. Identification of Commercial Fertilizer Materials, 1914, U. S. Dept. Agri. Bul. 97. Wright, F. E. The Petrographic Microscope in Analysis, Jour. Amer. Chem. Soc., 1916, **38:** 1647–1658. Chamot, E. M. Chemical Microscopy, Jour. Ind. Eng. Chem., 1918, **10:** 60–66.

[3] To be published in the Jour. Amer. Chem. Soc.

OBSERVATIONS.

Samples are prepared by gently crushing the dry substance. A minute amount is immersed in a drop of a liquid in which it is insoluble, on a glass slide, and protected by a small cover glass. The observations are made as follows:

I. IN ORDINARY LIGHT.

A 16-millimeter ($\frac{2}{3}$-inch) objective is usually most satisfactory for the preliminary examination of a substance.

Color or hue.—If the substance is pleochroic, showing different colors in different crystallographic directions, the several colors and their directions are recorded.

Crystal habit.—This observation includes the outline of crystals, etc.

Angles.—Interfacial angles are measured by revolving the stage of the microscope until the trace of each face in turn lies parallel to one of the cross hairs, and reading the angular position of each. This process is repeated several times, and the results averaged.

Cleavage.—Cleavage refers to the directions in which splitting along definite planes occurs.

Refractive indices.—These are inversely proportional to the rates at which light is transmitted in different crystallographic directions. They are determined by immersion in liquids of known indices, trying one after another until the boundaries in each direction successively disappear. The following special instructions are important: In crystals of the rhombic, monoclinic, and triclinic systems there are three indices, the smallest being called α, the intermediate β, and the largest γ. The directions in which these values hold are respectively X, Y, and Z. In substances of the tetragonal, trigonal, and hexagonal systems there are two indices, one called ω and the other ϵ. In the cubic system there is but one index, called n.

Determination of refractive indices by the immersion method.—A series of liquids of known indices should first be prepared, the composition of which depends on the nature of the substance to be examined. With the alkaloids studied, solutions of potassium-mercuric iodid in glycerol and water were found to be fairly satisfactory.

The stock solution is prepared as follows: Mix equal volumes of water and pure glycerol. In this dissolve 2.88 grams of potassium iodid and 3.38 grams of mercuric iodid per cubic centimeter of liquid; evaporate the solution on the water bath to the point of incipient crystallization; at 20° its index is approximately 1.71. Dilute this with glycerol (index 1.42) in the calculated proportions to make liquids with indices differing by a uniform amount, preferably 0.01. Measure the true indices of these liquids on a refractometer, or by other means, and correct the indices by the addition of glycerol or of stock solution, as necessary. The liquids are best kept in small dropping bottles, protected by glass caps.

A few crystal grains are immersed in a drop of one of the liquids on a slide, and the relative indices of grain and liquid determined thus: The light entering the microscope is diminished by means of the substage diaphragm, and a grain is brought into focus. Then, on raising the microscope tube slightly, a band of light passes into that substance—crystal or liquid—having the higher refractive index in that direction. The more divergent the indices of the two, the more brilliant the band; while when they are nearly matched, the band becomes faint, and, if white light is used, shows pale blue and orange margins. When the two have the same indices, no light moves in either direction. For accurate matching, monochromatic light, such as that from a sodium flame, should be used. White light passed through a ray filter is convenient. The writer uses a combination of Wratten E-red No. 23 and B-2 Extra Light No. 57-A filters, 3 inches square, in glass.

Crystals belonging to the cubic system have but one index, and their position is of no significance. Those of other systems, however, possess more than one, and the position in which they are observed must be taken into consideration. The grain to be studied should first be turned until it becomes dark or "extinguished" between crossed nicols. If the lower nicol prism, the polarizer, is inserted alone, two indices can be observed on any one grain, one when it is parallel, the other when it is perpendicular, to the direction of vibration of this nicol. If the elongation of the grain is positive, the highest index is shown when it is parallel, the lowest when perpendicular; if negative, the reverse relation holds. When the substance crystallizes in one of the less symmetrical systems, and has three different indices, grains lying in different crystallographic directions must be observed in order to measure all three.

II. IN PARALLEL POLARIZED LIGHT.

Parallel polarized light is produced by inserting the crossed nicol prisms.

Extinction (the directions in which the crystal becomes dark).—Extinction is said to be parallel when it occurs on bringing a long axis or side of a grain into parallelism with one of the cross hairs, and inclined when it occurs in some other position. When inclined, the angle between the axis or side and the cross hair is measured and recorded as the extinction angle. Several measurements are made, and the maximum value used. Crystals of the tetragonal, trigonal, hexagonal, and rhombic systems show normally parallel extinction, as do also monoclinic crystals elongated parallel to axis *b*. Crystals of the cubic system are dark in all positions, and are said to be isotropic; they show none of the phenomena hereafter listed.

Double refraction (birefringence).—This is the difference between the highest and lowest indices of refraction. It is described as weak, moderate, strong, etc., and is estimated by the order of the polarization colors shown when the grain is midway between two extinction positions.

Determination of the double refraction by order of polarization colors.—The polarization color obtained by placing any doubly-refracting crystal grain between crossed nicols is dependent on its thickness and the strength of its double refraction. Table 1 gives the colors with different thicknesses and double refractions.

TABLE 1.—*Colors observed with various thicknesses and double refractions.*

Color	Double refraction ×thickness.	Color.	Double refraction ×thickness.
First order:	*Mm.*	Third order:	*Mm.*
Black	0.00000	Light violet	0.00115
Gray	.00005	Light blue	.00120
White	.00020	Light green	.00135
Yellow	.00035	Light yellow	.00140
Orange	.00045	Light orange	.00145
Red	.00052	Light red	.00155
Red-violet [1]	.00055	Light red-violet	.00160
Second order:		Fourth order:	
Violet	.00057	Pale violet	.00170
Blue	.00065	Pale blue	.00180
Green	.00080	Pale green	.00190
Yellow	.00090	Pale yellow	.00200
Orange	.00095	Pale orange	.00210
Red	.00105	Pale red	.00230
Red-violet	.00110	Pale red-violet [2]	.00240

[1] Sensitive tint, shown by the selenite plate.
[2] Fifth order colors are extremely faint, and higher orders are white.

The selenite plate may be used to determine the order of the color, provided it is not too high. The plate is inserted, and the crystal is observed when parallel and again when perpendicular to its direction *c*. In one direction the color of the grain will be of lower order, in the other of higher order, than the selenite, which itself yields red-violet between the first and second orders. Even though the order, can not be determined on the crystal alone, the order of the combination of crystal and selenite can usually be told in one direction at least. As the selenite adds or subtracts just one order to or from the color produced by the crystal alone, the order of the crystal can thus be calculated. The thickness of the grain is best measured by focusing first on the top and then on the bottom, and noting how much the fine adjustment head has been turned.

Sign of elongation [1] (*positive or negative*).—The elongation is positive when the greater of any two indices lies in the direction of the longest axis or dimension of a given grain, and negative when the lesser of two lies in that direction. This may be ascertained by observing elongated grains immersed in a medium possessing the same mean refractive index, in light passing through but one nicol prism, of which the direction of vibration is known. This last property is most readily determined by observing a few needlelike crystals of a dark-colored variety of the mineral tourmaline. The darkest color is always shown when these lie with their long axis perpendicular to the vibration direction of the nicol prism. If the grain under observation shows the lowest refractive index when its long dimension is perpendicular to the vibration direction of the nicol, and the highest when parallel to this, its elongation is positive. In the reverse case it is negative. The sign may also be ascertained by the use of the selenite plate. Crystals showing as low double refraction as possible are turned so that their longer dimensions are parallel to direction *c* of the plate, which is placed so as to make an angle of 45° with the vibration planes of the nicol. If the polarization color is intensified, so that the crystal appears blue, or other color of a higher order than the red-violet due to the selenite plate, the elongation is positive; if the crystal appears yellow, white, or gray, that is, of lower order color than the red-violet field, the elongation is negative. Turning the crystal through 90° so that its long direction is perpendicular to axis *c* of the plate gives the opposite result, the color decreasing in order if the elongation is positive and increasing if it is negative.

III. IN CONVERGENT POLARIZED LIGHT.

Convergent polarized light is produced by raising the substage condenser as close to the slide as possible and using a high-power objective, preferably one of $\frac{1}{6}$ inch or 4 millimeters. After a grain is centered, the eyepiece is removed, or a Bertrand lens inserted, if the microscope is provided with one, and the stage, or nicol prisms, slowly revolved.

---

[1] Strictly, "character of principal zone."

Class[1] may be *uniaxial*, possessing but one optic axis, or *biaxial*, possessing two. If biaxial, the angle between the two may be measured, for which purpose an apertometer or a micrometer eyepiece is needed. For the determinative work on alkaloids, however, it is necessary only to class the angle as small or large.

A uniaxial interference figure consists of a dark cross surrounded by rings which are colored if white light is used, or alternately dark and light in monochromatic light. It may appear in the center of the field if the crystal is lying on face *c*, the base, or it may lie more or less to the side. Even when the cross is not visible the dark arms will, on revolving the stage, move across the field parallel to each cross hair in turn, remaining perfectly straight.

A biaxial interference figure consists, in the most favorable case, of two dark spots, where the two optic axes emerge, surrounded by concentric oval or lemniscate curves, colored as in the uniaxial interference figure, and traversed by two dark bars which form a cross when the vibration directions of the crystal are parallel to those of the nicol prisms, and open out into hyperbolas when the stage is rotated 45°. The apparent angle, 2 E, is proportional to the distance separating these dark spots; the acute bisectrix lies midway between them. Two or three sheets of mica should be used for forming an idea of the appearance of the interference figures with different values of 2 E. Muscovite mica has 2 E from 60 to 70°; while phlogopite usually has 2 E much smaller, about 15°. In some positions only portions of the figure may be visible, but, in general, on revolving the stage the dark bars move across the field, neither parallel to the cross hairs nor remaining straight.

Optical sign[2] (*positive or negative*).—Uniaxial crystals are positive if ω is less than ϵ; negative if ω is greater than ϵ. Biaxial crystals are positive if Z is the acute bisectrix and negative if X occupies that position. This is determined in the same way as is the sign of elongation (page 6). That is, the selenite plate is inserted, and the change of color of the interference figure observed; when the figure shows, on opposite sides of the central cross, areas of blue, marking an increase in the order of the color in a direction parallel to *c* of the plate, the sign is positive; when the color is yellow in that direction, indicating a decrease, the sign is negative.

Dispersion.—Dispersion is the relative refraction of the red end of the spectrum as compared with the violet end, abbreviated to *r* and *v*, respectively. This can be observed in various ways, but, as it has in general little or no significance in the identification of alkaloids, it will not be further discussed here.

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[1] Strictly "ellipsoidity."

[2] Strictly "character."

MEASURING THE OPTICAL PROPERTIES OF AN ALKALOID.

Before measuring the optical properties of any substance, its purity must be established, for admixtures may modify some or all of its constants to a marked degree. The medium from which it is crystallized must also be taken into consideration, as some substances take up the liquids, in the form of "solvent-of-crystallization," and the crystallographic and optical characters may differ widely from one solvent to another. For instance, the alkaloid quinidine is recorded in the literature as crystallizing from acetone in the tetragonal system, being optically uniaxial, from methyl and other alcohols in the rhombic system, with axial ratios near 0.8:1:0.7 and with an optic axial angle (2 E) about 75°, and from benzene, also rhombic, but with the axial ratios nearer 0.7:1:1.1 and an optic axial angle of 85°. These differences are such that the crystals from these several solvents would be identified crystallographically or optically as belonging to different chemical substances by an observer not previously informed as to their character. Anyone desiring to gain familiarity with the manipulation of the microscope, and with the sort of effects upon which this method of identification of substances is based, may follow the directions outlined for the typical case described in the next paragraph.

Dissolve a 5-gram sample of cinchonine alkaloid in 100 cc of boiling 95 per cent alcohol. Filter the solution and allow it to cool, when the alkaloid is deposited on the walls of the vessel in small, brilliant crystals. Take out a few crystals, dry, crush, and mount them on a slide in potassium-mercuric iodid solution with a refractive index of about 1.61. Examined first with a low-power objective, in ordinary light, cut down by the substage diaphragm, the material shows plates and rods, many of them with hexagonal outlines. When the lower nicol is inserted, with its plane of vibration horizontal (right and left), all of the grains with their long dimensions horizontal stand out boldly, and light appears to pass into them as the tube is raised, indicating their refractive index lengthwise to be higher than that of the liquid. Many grains with their long dimensions vertical show faint orange and blue borders, indicating that the refractive index crosswise approximates that of the liquid, although, as this index is the mean between the two lower ones of the substance, it varies with the position in which each grain happens to lie. When both nicols are inserted and crossed, the diaphragm being now opened to obtain as bright an illumination as possible, the majority of the grains are white, or have hues of the fourth order, because of the extremely strong double refraction, with several marginal color bands, due to the wedge-shaped edges. A few grains show brilliant hues of lower orders, because of extreme thinness or because they are so turned that two refractive indices which are not very dissimilar are shown. When the stage is turned they, for the most part, become dark when their long dimensions are nearly or quite parallel with one of the cross hairs, although in some grains this extinction is not complete in any position. When a high-power objective is inserted and focused on a grain, the nicols remaining crossed, and the eyepiece is removed, nearly every grain shows a portion of a biaxial interference figure, colored rings, with one or two strongly curved dark bands crossing them as the stage is revolved. In some cases the points of emergence of both optic axes are in view simultaneously, and they are fairly close together, showing that the axial angle is small.

If it is desired to identify this substance in a drug mixture, the alkaloid contents may be extracted with chloroform, dried, taken up in benzene, and allowed to stand until the solvent is nearly evaporated. Single large drops of the concentrated solution are placed on several microscope slides, and immediately protected by cover glasses. Evaporation takes place around the edge of the covers, and there the alkaloids crystallize. When the benzene is completely volatilized, the immersion liquids may be introduced, and the appropriate observations made.

SUMMARY.

It seems reasonable to hope that optical-crystallographic measurements will furnish a ready and certain means for the recognition of a number of crystalline alkaloids, even when they are mixed in widely divergent proportions. The observations made on such substances with the apparatus and according to the methods described in this bulletin were most successful in establishing the identity of a number of these substances.

PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE RELATING TO THE SUBJECT OF THIS BULLETIN.

AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

Identification of Commercial Fertilizer Materials. (Department Bulletin 97.)

The Application of Optical Methods of Identification to Alkaloids and Other Organic Compounds. (Department Bulletin 679.)

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Official and Provisional Methods of Analysis, Association of Official Agricultural Chemists, as Compiled by Committee on Revision of Methods, Nov. 1, 1906. Provisionally Adopted by Association, Further Revised and Finally Adopted October, 1906. (Bureau of Chemistry Bulletin 107.) Price, 20 cents.

Proceedings of Twenty-seventh Annual Convention of Association of Official Agricultural Chemists, Washington, D. C., 1920. (Bureau of Chemistry Bulletin 137.) Price, 25 cents.

American Mineral Waters: New England States, With Chapter on Bacteriological Methods. (Bureau of Chemistry Bulletin 139). Price, 15 cents.

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Proceedings of Twenty-eighth Annual Convention of Association of Official Agricultural Chemists, Washington, D. C., 1911. (Bureau of Chemistry Bulletin 152.) Price, 35 cents.

Determination of Lithium. (Bureau of Chemistry Bulletin 153.) Price, 5 cents.

Proceedings of Twenty-ninth Annual Convention of Association of Official Agricultural Chemists, Washington, D. C., 1912. (Bureau of Chemistry Bulletin 162). Price, 25 cents.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 680

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER August 14, 1918

MISCELLANEOUS CONIFERS OF THE ROCKY MOUNTAIN REGION.

By George B. Sudworth, *Dendrologist.*

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SCOPE OF THE BULLETIN.

This bulletin deals with the distinguishing characteristics, forest habits, and geographic distribution of all the larch, hemlock, false-hemlock, incense cedar, arborvitæ, and yew trees that grow naturally within the Rocky Mountain region. The extent of the territory included in this region is indicated in a recent publication on "The Cypress and Juniper Trees of the Rocky Mountain Region,"[1] which also contains a full discussion of the class and family relationships of the true coniferous trees here described, as well as information applicable in the present case regarding the method of treating the subject, the sources from which data on the geographic range of trees were obtained, and the like. Acknowledgments made in the above-mentioned publication of assistance received apply also in the case of the present bulletin.

Keys for the identification of genera and species are provided on page 44.

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[1] Bulletin No. 207, U. S. Department of Agriculture, p. 1, 1915.

GENERIC CHARACTERISTICS OF LARCHES.

The larches,[2] some of which are also called tamaracks, belong to the genus Larix.

They lose their leaves every autumn, their branches becoming bare in winter and in the spring putting forth new foliage. The branches occur irregularly on the trunks, differing in this respect from the branches of pines, spruces, and balsam firs, which are regularly whorled. The leaves resemble somewhat those of other conifers in being needle-shaped; but they are distinct in arrangement from the remainder of our native cone bearers in being produced in little brushlike clusters, each of which contains from 12 to 40 leaves (Pls. I, II, III). These clusters are borne on all but the leading or new shoots, on which the leaves are scattered singly (Pl. III, *b*). The little budlike spurs that bear clusters of leaves are really aborted or partly suppressed branchlets, which, if conceived to be extended by growth, would show their leaves disposed singly as on the leading shoots.

Both the male and female flowers, which appear with the new leaves, are borne singly and separate from each other on the same branches or twigs of the previous or an earlier year's growth. The male, or pollen-bearing, flowers are small, budlike, rounded, or elongated, yellow-green bodies about the size of a small pea, and are borne naked. Female flowers, which produce cones and seeds, are similarly small, elongated bodies composed of tiny scales, at the bases of which are borne two minute naked ovules. The female flowers are usually a bright purple or red. They are accompanied by a bundle of leaves.

The cones mature in a single season, but they often remain on the trees for one or more seasons after maturity. Two winged seeds are borne under each of the thin fertile cone scales (Pl. III, *d*). Larch cones open in the autumn shortly after they are matured, and shed their seed. The seed-leaves (cotyledons) vary in number from 5 to 7. Succeeding these, the young stem bears single scattered leaves, just as do also the leading or young shoots from branches of old trees. Seedlings continue to bear single leaves for several years, after which they produce the adult clusters of leaves.

The larches are important timber trees. They produce straight, tall stems, the wood of which is slightly resinous, strong, and moderately durable. The largest trees supply excellent saw timber.

At least three distinct species of larch inhabit the United States. One is found mainly in northeastern United States and adjacent

---

[2] The name Larch (from the Latin Larix, a larch tree) is properly applied only to trees of the genus Larix. During the last 25 years, however, "larch" has been, and is still, improperly used by Pacific slope lumbermen and woodsmen as a name for the noble fir, Abies nobilis, which is a true fir or "balsam" in no way directly related to the larches. This use of the name "larch" should be discontinued, for it has led to much unnecessary confusion.

Canadian Provinces, from which it extends westward to southern Alaska. The other two species inhabit northwestern United States xtending northward also into Canada. A fourth species, not now ully known, is possibly confined to Alaska.[3]

The larches are of ancient origin, several European species having xisted since the Miocene period. The European larch (*Larix uropæa*) appears in the upper Pliocene of Europe and is represented hroughout the Pleistocene, while our eastern larch (*Larix laricina*) s common in this country during the Pleistocene period.[4]

TAMARACK.

Larix laricina (DuRoi) Koch.

COMMON NAME AND EARLY HISTORY.

Larix laricina is most commonly known throughout its range as amarack, particularly among woodsmen. Sometimes it is also called larch, black larch, red larch, and hackmatack.

Tamarack was one of the first of our conifers to become known, he earliest report of it being as a tree cultivated in England in 1735.[5] The early French Jesuit missionary and historian Charlevoix saw he tamarack in eastern Canada and gave the first complete published account of it in 1744 [6] ("Larix canadensis, longissimo folio"). However, the earliest mention of this species is doubtless by John Josselyn,[7] who describes the great lasting qualities of a "Larch tree" observed in New England in 1667, which can be none other than our amarack. The first technical description and (polynomial) designation [8] of tamarack was published in 1770, while the first technical binomial designation, Pinus laricina DuRoi [9] was published in 1771. The technical name Larix laricina (DuRoi) Koch, now properly maintained for this tree, was established in 1873.[10]

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[3] See Smithsonian Miscellaneous Collections, vol. 50, p. 174, Pl. XVII, 1907; Forest Trees of the Pacific Slope, p. 74, fig. 28A, 1908 (U. S. Dept. Agr.).

[4] The author is indebted for this information to Dr. Edward W. Berry, paleontologist of John Hopkins University.

[5] Aiton, Hortus Kewensis, III, 369, 1789.

[6] Histoire de la Nouvelle France (ed. 12 mo.) IV, 371, fig. 22, 1744.

[7] An Account of Two Voyages to New England, 68, 1673.

[8] "Pinus Larix Americana nigra", Muenchhausen, Hausv., V, 226, 1770.

[9] Obs. Bot., 49, 1771.

[10] William Aiton (Hort. Kew. III, 369, 1789) says that this larch was cultivated in England in 1735. According to Loudon (Arb. et. Frut., IV, 2401, 1838), a form of this larch ("Larix a. pendula") was introduced into England by Peter Collinson in 1739, while another form ("Larix a. rubra") was introduced by the Duke of Argyle in 1760, the latter tree having attained a height of 40 or 50 feet in 77 years. Elwes and Henry (The Trees of Great Britain and Ireland, II, 394, 1907) say that modern English arboriculturists have entirely neglected this tree. Only a few trees are now known in England, the largest being from 50 to 78 feet high and from 18 to 20 inches in diameter.

Larix laricina is little used as an ornamental tree in the United States, probably because it is believed the tree can not be grown outside of its natural habitat in wet, mucky ground. It is, however, well adapted to rich, sandy or gravelly upland soils that are fairly moist and deep. Under such conditions it grows rapidly and to a large size and has a beautiful symmetrical form.

DISTINGUISHING CHARACTERISTICS.

The largest tamarack trees in the Rocky Mountain region are seldom over 50 feet high and 12 or 14 inches in diameter. Tamarack has a single straight, slightly tapering trunk, and a narrow, sharply conical crown of slender, horizontal branches, which, during the first 25 or 30 years, extend nearly down to the ground. Later the trunks are clear of branches for one-half or two-thirds of their length. The thin, scaly bark is reddish brown, but outwardly more or less weathered to an ashy brown. Twigs of a season's growth are smooth and whitish at first, but by winter they become a dull yellowish brown.

Mature leaves (the juvenile form is scattered singly on vigorous leading shoots) occur in clusters of about 12 to 20 (Pl. I), and are indistinctly triangular in cross section (convex on the top side, with a ridge beneath) and from about seven-eighths of an inch to 1⅛ inches long. In cross section the leaf shows two minute resin ducts close to its edges.

The cones (Pl. I), matured in early autumn of one season, are pale russet-brown, as are the minute-winged seeds (Pl. I, *f*), which escape slowly from the gradually opened cone scales during late autumn or early winter; the upright position of the cones doubtless prevents the seeds from escaping as rapidly as do the seeds from the pendent cones of other conifers.

Wood of the tamarack is a pale yellowish brown, and varies in texture from narrow-ringed to moderately wide-ringed, according as the trees are grown in dense or open stands. It is rather hard and heavy, durable, elastic, and fairly straight-grained,[11] a cubic foot of dry wood weighing nearly 39 pounds. Large trees have a rather thin layer of whitish sapwood, which is much thicker in young trees. The wood is used chiefly for telegraph and telephone poles and for railroad ties, the largest trees being cut for rough lumber.

OCCURRENCE AND HABITS.

Tamarack enters the Rocky Mountain region (Map No. 1) only north of the Canadian boundary, and occurs mainly on the east side of the Canadian Rockies. It is most abundant in sphagnum swamps and muskegs; but the largest trees occur on the better-drained margins of swamps and lakes, moist, porous benches, and bottom lands. It thrives also on moist, well-drained deep-soiled hillsides. In the Rocky Mountain region the tamarack grows at elevations between about 600 and 1,700 feet; its vertical distribution elsewhere in its range is, however, imperfectly known at present.

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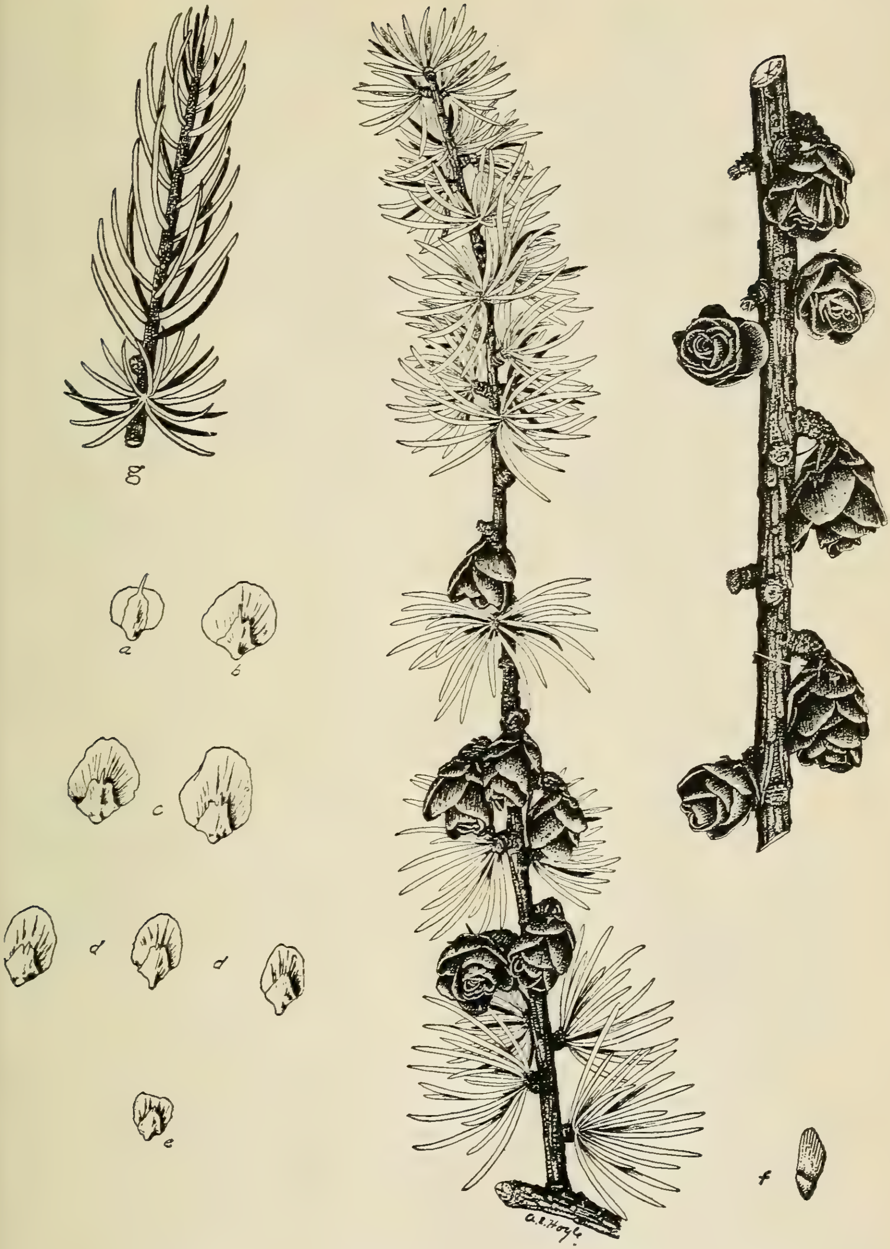
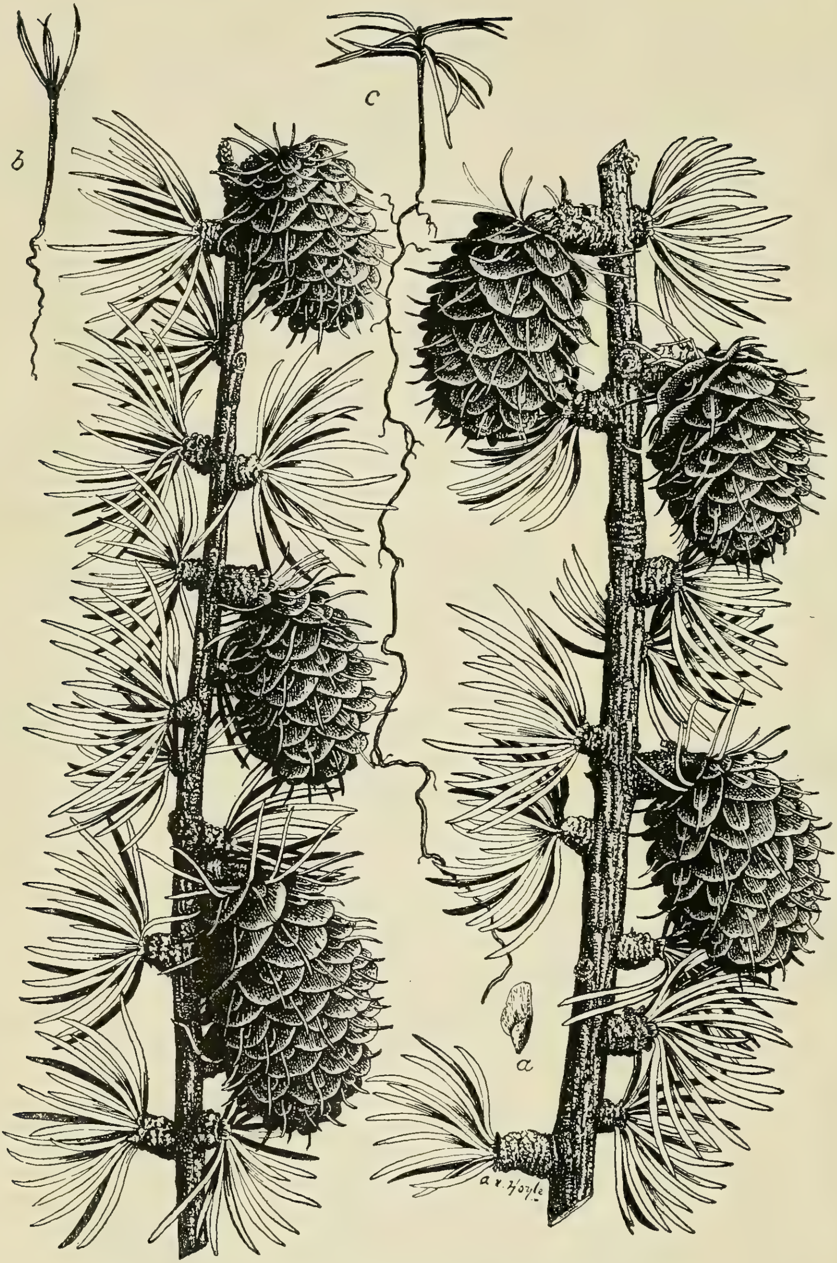
[11] Old trees often have an outer layer, 3 to 4 inches thick, spirally twisted, within which the earlier formed trunk wood is straight-grained.



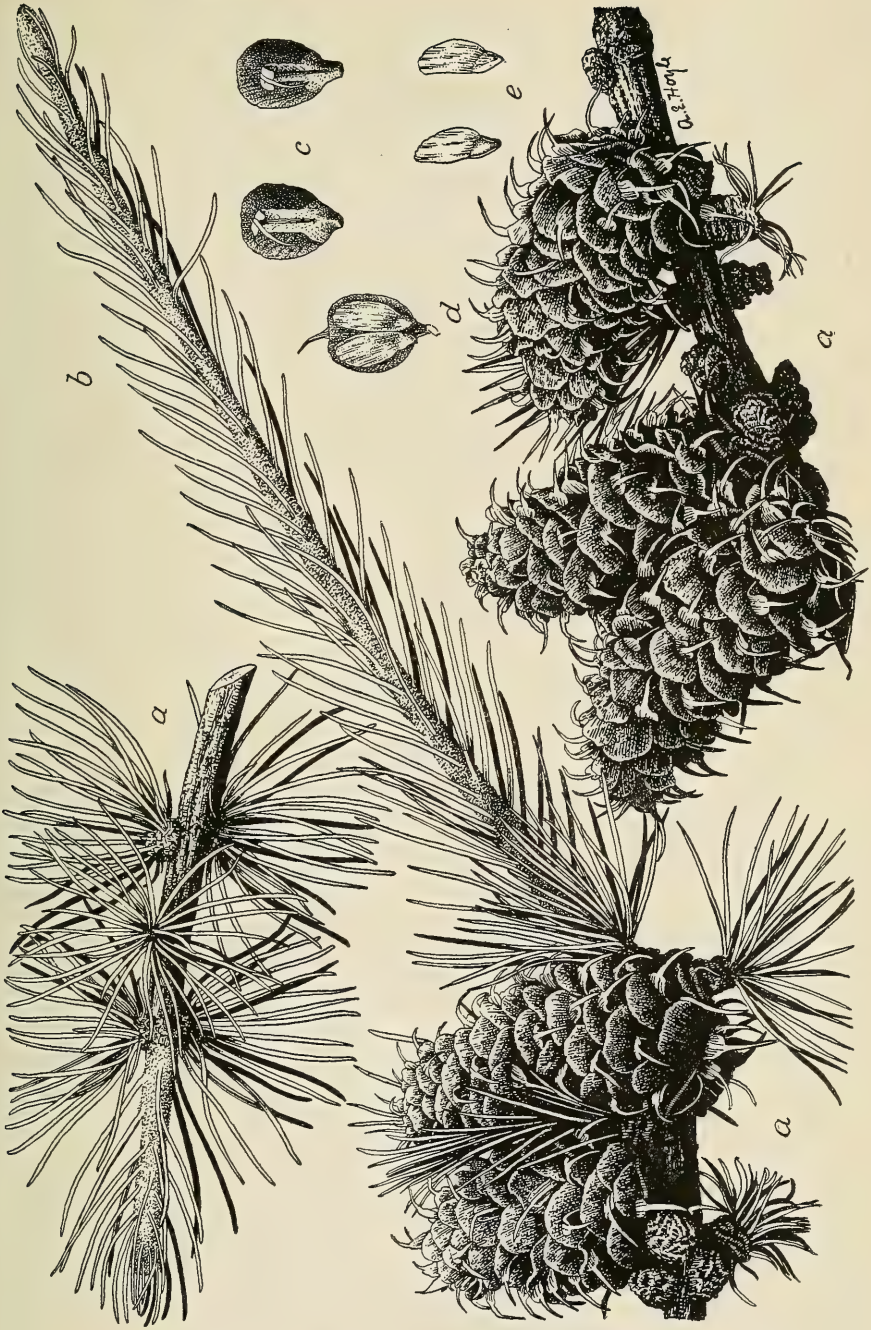
Larix laricina: Foliage and Leafless Branch with Old Persistent Open Cones.

a, Cone scale at base of cone; *b*, scale near base; *c*, scales from center of cone; *d*, *e*, scales near top of cone (all enlarged 1½ times natural size); *f*, seed with its wing (natural size); *g*, terminal shoot with juvenile or primary leaves.



LARIX OCCIDENTALIS: FOLIAGE AND CLOSED CONES.

a, Upper side of seed with wing; *b*, seedling 2 weeks old; *c*, seedling 6 weeks old.



LARIX LYALLII: FOLIAGE AND CONES.

a, Clusters of foliage and open cones; *b*, primary or juvenile leaves of new shoot; *c*, cone scales showing their protruding bracts; *d*, upper side of cone scale with its seeds; *e*, upper (left) and lower sides of seeds with wings.

The tree grows on shallow, moist soils of nearly every consistency, from stiff clay to coarse sand, but thrives on moderately retentive loams, especially those with rich leaf mold. The occurrence of tamarack in saturated soil seems to indicate not so much a special requirement as it does ability to exist where other species more tolerant of shade can not grow. Tamarack does not grow well, however, where its roots are constantly submerged, particularly during the summer season. It occurs in open scattering stands mixed with black spruce, black cottonwood, alder, and willows, or sometimes forms rather dense, pure growths of limited extent. Even in the closest stands, however, the crown cover is never very dense, for it requires a great deal of light throughout life, at no time enduring heavy shade.

Larix laricina produces seed abundantly about every 2 to 4 years, some seed being borne annually. Trees begin to bear cones at an age of from 10 to 20 years, seed production increasing rapidly thereafter up to an age of about 100 years, after which it decreases in amount and regularity. The seed has only a moderately high rate of germination and fairly persistent vitality. Conditions favorable to germination of the seed and early growth of the seedlings are fresh organic or mineral soil, with a sparse protecting cover of grass or herbs. Seedlings require this slight protection at first; afterwards in full light they grow fairly rapidly in height, so that they persist in mixture with more tolerant but slower growing species of the same age.

LONGEVITY.

The largest trees are from 150 to 180 years old; those from 10 to 12 inches through are from 60 to 75 years old.

WESTERN LARCH.

Larix occidentalis Nuttall.

COMMON NAME AND EARLY HISTORY.

Western larch is known to lumbermen and settlers in its range only as "larch," a name which is applied more or less also to other native species of Larix. The common name western larch, a literal translation of the technical name, is suggested in order to avoid confusion.

The first discovery of Larix occidentalis was made in 1806 by by Lewis and Clark,[12] whose narrative tells of finding a "larch tree," now believed to be the western larch, on the upper Clearwater River in western Montana. It is evident that the Scotch explorer David Douglas[13] was the next one to observe this tree, on the Columbia

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[12] History of the Expedition under command of Lewis and Clark (ed Coues), III, 1043, 1066, 1806.

[13] Companion Botanical Magazine II, 109, 1836.

River in the vicinity of Fort Colville, northeastern Washington, in 1827, although he believed it to be Larix europæa. It was not, however, until 1834 that the western larch was really recognized as a new and undescribed species, Thomas Nuttall having discovered the tree at that time in the Blue Mountains of northeastern Oregon. Later, in 1849, he described and named it Larix occidentalis. Since then, the history of western larch has been practically free from confusion, but one other name ("Pinus Nuttallii Parlatore," 1868), now a synonym, having been given to the tree during the long period it has been known.[14]

DISTINGUISHING CHARACTERISTICS.

Larix occidentalis is the largest and most massive of North American larches. Its straight stems grow ordinarily to a height of from 100 to 180 feet, and to a diameter of 3 or 4 feet. Not infrequently, however, trees reach a height of over 200 feet and a diameter of from 5 to 8 feet. The tapering trunks are clear of branches for from 60 to 100 feet or more. The crown is a short, narrow pyramid running up to a long slender point, and is very open, being made up of comparatively few, small, horizontal branches, which have the appearance of being thinly clad with leaves. Trees growing in protected situations at low elevations have rather long, narrow crowns, with more or less weeping branches. In exposed places at high elevations this weeping habit is much less pronounced.

Middle-aged and old trees have reddish cinnamon-brown bark, which is 3 to 6 inches thick and deeply furrowed near the base of the tree, where the ridges are strikingly massive; 20 or more feet above, it is much thinner and less deeply furrowed. The exceedingly thick bark on the lower trunks of large trees is often an effective protection against injury by fire, many of these trees having passed through several destructive forest fires without damage to their vitality. The bark of young trees and branches is thin, scaly, and dark or grayish brown.

The color of the foliage is a pale yellowish green, in late autumn becoming a bright lemon-yellow, which distinguishes the trees from their associates. The flatly triangular leaves, rounded on the back and distinctly ridged or keeled on the inner face, are from about 1 inch to sometimes 1¾ inches in length. In cross section they show a single fibrovascular bundle in the center and no resin ducts. The number of leaves in a cluster (Pl. II), which can not be depended upon as a distinctive characteristic, ranges from 14 to about 30.

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[14] Western larch was first introduced into England in 1881 and again in 1889 only 1 of 40 seedlings received in 1881 surviving, and but 2 out of 10 received in 1889. Elwes and Henry (The Trees of Great Britain and Ireland, II, 396, 1907) say that in 1906 these trees measured, respectively, 33 feet in height and 5⅜ inches in diameter, and 29 feet in height and 5⅝ inches in diameter.

Larix occidentalis was cultivated for the first time in eastern United States, near Boston, in 1881, the trial being made with wild seedlings obtained from Oregon. Prof. C. S. Sargent says (Silva, XII, 13, 1898) that these plants have remained stunted, which would seem to indicate that the species is not adapted to the climate of New England. However, twigs from them grafted on the roots of Japanese larch have grown vigorously. We do not know of any other trial of western larch in the East. The great difficulty, however, in obtaining seed doubtless explains why so little has been done to test this tree in the East.

The cones (Pl. II) mature in one season, being ripe during the latter part of August and early in September. They open soon afterwards and shed their light chestnut-brown seeds (Pl. II, *a*). By the end of October or November all of the cones have fallen from the trees. The cones are borne on very short footstalks and vary in length from about 1 inch to 1½ inches. The cone scales are usually densely coated on the outside below the center with delicate, whitish, woolly hairs. The seed-leaves of western larch are, as a rule, 6 in number (Pl. II, *b*, *c*).

The commercially valuable wood is of a clear reddish brown color, and usually narrow-ringed, with a comparatively thin layer of whitish sapwood. It is strong, and very durable in an unprotected state, differing greatly in the latter respect from wood of the eastern larch (*Larix laricina*). Western larch wood is much used locally for lumber and for rails and shakes. The largest general use, however, is for telegraph and telephone poles, railway ties, and posts. It is the heaviest of our larch woods, a cubic foot of the dry wood weighing a little over 46 pounds.

OCCURRENCE AND HABITS.

Larix occidentalis grows on mountain slopes, preferring north and west exposure, stream bottoms, valleys, and flats at elevations between about 2,000 and 7,000 feet. It is rare in the bottoms of canyons and on the summits of mountains (Map No. 2).[15] As the tree is very exacting in its requirements of soil moisture, the best growth occurs in deep, fresh, porous soils; it will, however, maintain itself in low, moist places and in dry, gravelly soils.

Western larch sometimes forms pure stands, but it usually occurs mixed with other trees. Its best growth is in northeastern Washington, northern Idaho, and northwestern Montana, where it often occurs in pure open forests in valleys and on slopes. Trees of largest size are found at lower elevations along Priest River (Idaho) in mixture with western white pine, western red cedar, Douglas fir, western hemlock, Engelmann spruce, and lowland white fir. Somewhat higher up it becomes an important part of Douglas fir forests, here being associated with lodgepole pine, western white pine, lowland white fir, alpine fir, and Engelmann spruce. In the Bitterroot Mountains (northern Idaho), it grows in pure stands or is mingled with small numbers of Douglas fir and western yellow pine.

Western larch is very intolerant of shade throughout life, probably demanding even more light than western yellow pine. The disadvantage of this intolerance is partly overcome by early rapid height growth, which carries the tree above its suppressing heavier-foliaged associates. It appears to be more tolerant on moist soils than on dry ones. In moist sites it occurs in fairly dense stands, and the trees are tall and with clear boles, but the lower branches are early killed and dropped; on drier soils, where open stands or isolated trees are more common, the branches are often retained for many years down to the ground.

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[15] The author's cordial thanks are due to Dr. H. N. Whitford for valuable notes extending the range of Larix occidentalis in British Columbia.

Western larch is a prolific seeder, but it is locally variable in seed production, sterile periods of one or more seasons being common. It rarely bears seed as early as the twenty-fifth year, but begins to produce it abundantly when 40 or 50 years of age. The seed has a fairly high rate of germination and moderately persistent vitality. The thin scales of ripe cones open and close readily with alternate dry and wet weather, so that the period and the rapidity of seed dispersion vary somewhat with local climatic conditions. Usually, much seed is shed on the snow. Abundant moisture in the soil is required for germination of the seed and growth of the seedlings. The chief competitor of larch is lodgepole pine, the soil conditions for the reproduction of these trees being very similar, as is shown by their frequent association. Both find suitable seed beds in burned-over areas with exposed mineral soil, where the order of reproduction frequently depends upon whether the larch or pine has seeded the ground first. If lodgepole pine has the start, it shades out the much more intolerant larch. If both species start together, larch may preserve its numerical importance in the stand by more rapid height growth. Its light foliage can not prevent the growth of the pines, nor of spruce and firs, the typical occurrence of larch under these circumstances being in mixed stands. Favorite areas for pure larch reproduction are those so thoroughly burned over as to preclude the immediate heavy reproduction of lodgepole pine.

LONGEVITY.

Western larch is a long-lived tree, attaining an age ordinarily of from 300 to 500 years, while the largest trees are from 600 to 700 years old. Trees from 16 to 25 inches in diameter are from 225 to 300 years old.

ALPINE LARCH.

Larix lyallii Parlatore.

COMMON NAME AND EARLY HISTORY.

Larix lyallii is a little-known species, which is usually not distinguished by the ordinary observer from Larix occidentalis, most travelers in its high mountain habitat recognizing it only as a "tamarack" or "larch," while some have supposed it to be only a high

high mountain form of the western larch. A very few people know it as "woolly larch," a name suggested on account of the woolly young twigs. The book name "Lyall's larch," coined directly from the technical name of the tree, seems not to have gained current use. The common name alpine larch is very appropriate because it refers to the tree's characteristic alpine habitat near timber line, and may serve roughly to distinguish it from the closely related western larch.

Alpine larch was discovered on the Cascade Mountains[16] in 1860 by Dr. David Lyall, surgeon and naturalist to the International Boundary Commission which surveyed and determined the boundary between British Columbia and the United States from the Gulf of Georgia to the crest of the Rockies. In 1863 it was technically described and named Larix lyallii Parlatore, a name which has been maintained for it practically throughout the 50 years this tree has been known to science, but one other technical name, Pinus lyallii Parl., now a synonym, having been applied to it during this time.[17]

DISTINGUISHING CHARACTERISTICS.

Alpine larch usually is stunted in appearance, attaining a height of from 30 to 50 feet and a diameter of from 10 to 24 inches. Exceptionally large trees, sometimes found, are from 60 to 80 feet in height and 3 feet or more in diameter. The long, broadly pyramidal, open, pointed crown is often unsymmetrically developed, some of the branches being very long and big. As a rule, the ends of the branches turn upward, but frequently they droop consipcuously. In contrast to the brittle branches of western larch, they are tough and withy. A notable characteristic of the new shoots (Pl. III, *b*) is their dense coating of white, fine wool, which is retained, more or less, for two seasons, and from which the tree gained the name of "woolly larch."

The trunks are clear of branches for only about one-third or one-half the tree's height, and, as a result of exposure to strong winds, are often crooked or bent. The bark of mature trees is rarely more than seven-eighths of an inch thick. It is indistinctly furrowed, the irregular, flat ridges of loose scales being of a deep purplish or reddish brown color, while the smooth bark of the branches is an ashy gray, as is that of young trees, on which the bark is usually unbroken until they are 5 or 6 inches in diameter.

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[16] Lyall, Journal of Linnæan Soc., VII, 143, 1864. Dr. Lyall does not say whether he found this larch in the Oregon or Washington Cascades.

[17] Larix lyallii appears not to have been introduced into cultivation as yet either in Europe or in this country. However, the very great difficulty of obtaining seeds, because the tree grows only in rough mountainous sections not easily accessible, may partly account for this. The seeds are shed soon after they are ripe, and to secure them the collector must be on hand just prior to this event. Whether or not Larix lyallii can be grown successfully outside of the severe climatic conditions of its natural range is to be determined only by actual trial. It has little of special beauty in form or appearance to commend it for ornament over other native and exotic species now in cultivation, the chief interest in attempting to grow it being its unique botanical characteristics.

The foliage of alpine larch is a light, bluish green, turning bright lemon-yellow in autumn, after the first sharp frost. The tree is then readily detected by this color on distant high, inaccessible peaks and crests. The juvenile or primary form of leaf grows singly on new shoots. The adult leaves occur in clusters of from 30 to 40 or more. They are somewhat indistinctly 4-angled, and from about 1 inch to 1⅝ inches in length (Pl. III, *a*). A cross section of the leaf shows two resin ducts, one in each of the two smaller angles.

The cones mature in one season, ripening early in August, and opening soon afterwards to shed their seed. By late autumn most of the cones have fallen from the trees, a few sometimes remaining until early winter. They are from about 1½ to 2 inches long (Pl. III). The bristle-pointed bracts (Pl. III, *c*) that project from among the cone scales are a deep purple, while the cone scales are a deep purple-red. Their margins have a fringe of tangled, very fine white wool, which is also more or less spread over the outer surface of the scales. Mature seeds (Pl. III, *e*) are pale reddish brown. The seed-leaves are usually 5 in number.

The wood of alpine larch is of a clear red-brown or deep orange-brown color, with a thin layer of whitish sapwood. It is narrow-ringed, hard, and tough. It ranks second in weight among our native larch woods, a cubic foot of dry wood weighing about 44 pounds. While the wood is suitable for rough lumber, railway ties, and mine timbers, it is not used for these purposes, probably because of the generally small size of the tree and the fact that it grows only in rough, comparatively inaccessible places.

OCCURRENCE AND HABITS.

Larix lyallii inhabits high mountain slopes and plateaus at and near timber line at elevations between about 4,500 and 7,600 feet (Map No. 3). The tree shows a preference for northern aspects and often for ''passes,'' sheltered sides of crests, and high divides. Its environment is one of heavy snowfall, which comes early and remains well into the summer, or, in some parts of its range, throughout the year. It is very moderate in soil requirements, growing in the rockiest soil and even in crevices of rough granite slopes, provided there is abundant moisture. For the most part, alpine larch occurs in small, pure groves, or sometimes in open stands with white-bark pine, mountain hemlock, alpine fir, and Engelmann spruce. It appears to be hardier than these alpine associates, ascending higher than they do in moist basins and showing greater vigor; while its thin foliage, compact, strong trunk, tough branches, and firmly anchored roots enable it to withstand without serious damage the rigors even of high bleak summits.

Like the western larch, this alpine species is very intolerant of shade throughout its life. Little is known now regarding its seeding habits. Sometimes cones are produced abundantly, but apparently at infrequent and irregular intervals. Reproduction in the United States is generally scanty, seedlings never being numerous, which may be due to the fact that much of the seed falls on the snow and is carried away during spring floods.

LONGEVITY.

Alpine larch is a long-lived tree, attaining an age of from 400 to 600 years. Exceptionally large trees are doubtless 650 to 700 years old, or even older, the exact age limits being imperfectly known at present. Trees from 16 to 18 inches in diameter are from 470 to 510 years old.

GENERIC CHARACTERISTICS OF HEMLOCKS.

The hemlocks, which belong to the genus Tsuga, are evergreen trees with soft, flat, or rounded-triangular leaves (Pls. IV and V). Their branches grow from the trunk at irregular intervals, differing in this respect from the pines, spruces, and balsam firs, the branches of which occur in regular whorls. The slender terminal sprays of the hemlocks droop gracefully, and the slender leaders nod conspicuously from the tops of the crowns. Hemlocks are large trees with broad pyramid-shaped crowns and long, slightly tapering trunks, which have characteristically rough, hard bark narrowly ridged and furrowed. The bark contains tannin, which gives it an astringent taste, and when broken it displays a clear chocolate-red color.

The leaves, which have small, threadlike stems, are spirally arranged around the twigs. According to the form of the leaves and size of the cones our native hemlocks are divided into two groups. One group has rounded leaves, so arranged that they completely cover the upper side of the twigs, and large cones (Pl. V); while the other group has flat leaves so arranged that they appear to grow only from two opposite sides of the twigs, the cones of this group being comparatively small (Pl. IV). A twist in the stem of the leaves brings them into the characteristic positions described. The leaves of hemlocks are peculiar in having but one resin duct, which, as seen in a cross section of the leaf, is situated in the center of the leaf near the lower surface. Leaves of a season's growth remain on the trees for from about 3 to 6 years, giving the twigs a well-covered appearance.

The male and female flowers are borne separately on different parts of the same tree, on twigs formed the preceding season. The female flowers grow at the ends of the twigs, while the male flowers are borne singly from buds at the bases of the leaves near the ends of the branchlets. Female flowers, which produce cones and seed, are small, greenish, scaly bodies, while the male flowers, pollen-bearing only, are small yellowish bodies attached by threadlike stems. The cones of the hemlocks mature in one season, and are composed of thin overlapping scales, beneath each of which two winged seeds are borne (Pl. IV, *a*); only the scales in about the central half of the cones, however, bear fertile seeds, those above and below this part being imperfect. The seeds of hemlocks are peculiar in having minute resin cells at various points on the outer surface. The small light seeds are easily wafted by the wind and thus may be widely disseminated. The seed-leaves of our native hemlocks are from 3 to 4 in number and very short.

Hemlocks are important forest trees, both for saw timber and for tan bark. As yet their wood is of comparatively lower commercial value than that of the pines, firs, and spruces, which often grow with hemlocks. Unquestionably, however, the commercial importance of hemlock wood, particularly of the western hemlock, will be greatly increased as the supply of other timbers, abundant now, is reduced. Strangely enough, the superior quality of western hemlock timber has long failed to be fully appreciated because the wood has been assumed to be similar in quality to that of the eastern hemlock, to which the western wood is vastly superior.

Four species of hemlock are indigenous to the United States and adjacent portions of Canada. Two of these inhabit eastern United States and adjacent Provinces of Canada, and two are found in the north Rocky Mountain and Pacific forests.

The hemlocks are of ancient origin, remains of them having been found in the Miocene formation of Europe and Asia. Tsuga mertensiana, the mountain hemlock, has been found in the Pleistocene of Alaska.[18]

WESTERN HEMLOCK.

Tsuga heterophylla (Raf.) Sargent.

COMMON NAME AND EARLY HISTORY.

Western hemlock is known to laymen chiefly as "hemlock." From its very close general resemblance to the familiar eastern timber hemlock (*Tsuga canadensis* Carr.) many of the early settlers in the Northwest believed the western hemlock to be the same as the eastern species. The common name "western hemlock" is here adopted in order to prevent confusion of these trees, which are botanically distinct and, as northwestern lumbermen well know, very unlike in the qualities of their woods.

The British navigator George Vancouver gives the first published notice of this tree in 1798, in his narrative of a voyage [19] to the north Pacific coast, in which he mentions "the Canadian and Norwegian hemlock," a name that can refer only to the species we now know as Tsuga heterophylla. He first observed the tree on the shores of Puget Sound in 1792.

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[18] Fide Dr. Edward W. Berry; see footnote No. 4.

[19] Voyage of Discovery to the North Pacific Ocean and Round the World (1798).

The first technical name, "Abies heterophylla Rafinesque," applied to western hemlock, was published in 1832. The present accepted name, Tsuga heterophylla (Raf.) Sargent, which is based on that of Rafinesque, was, however, not established until 1898. From 1867 to the latter date western hemlock was generally known to botanists as "Tsuga mertensiana Carrière," which was published in 1867. But this name, which is based on "Pinus mertensiana Bongard" (published in 1831), Prof. C. S. Sargent has shown must be applied to our mountain or black hemlock.[20]

DISTINGUISHING CHARACTERISTICS.

Western hemlock is a large forest tree. Its tall, clean, smooth-looking trunks, fine foliage, and drooping branchlets distinguish it from all of its associates. The trunks taper very gradually. As a rule, the base of the trunk is not greatly enlarged, but many trees from seedlings grown on logs and stumps are irregularly buttressed. Forest-grown trees have small, narrowly pyramidal crowns of slender branches, and are from 125 to 175 feet high and from 2 to 5 feet in diameter. Occasionally trees are found which are nearly 200 feet high and 8 or 9 feet in diameter. The bark of the larger branches and young trees is thin, finely scaly, and russet-brown; that of old trunks is about 1¼ to 1½ inches thick, hard, deeply furrowed, and of a dark, russet-brown color tinged with red; the main wide, flat ridges are irregularly connected with one another by narrower diagonally disposed ridges.

In color the foliage is a deep, glossy yellow-green. It clothes the twigs thickly, but has a rather thin appearance because of the small size of the leaves. The leaves (Pl. IV) appear to grow mainly from two opposite sides of the branchlets—somewhat like the teeth of a comb. They are flat, with a central groove on the upper side, have rounded ends, and short, distinct, threadlike stems, and vary in length from about one-fourth to seven-eighths of an inch.[21] The leaf-bearing twigs, especially the newly formed ones of the season, are more or less minutely hairy.

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[20] Western hemlock was introduced into cultivation in Scotland by John Jeffrey in 1851 (Malcolm Dunn, in Journ. Royal Hort. Soc., XIV, 78, 1892). Mr. Dunn (op. cit.) states that this tree was soon afterwards planted elsewhere in the British Isles, where it generally seemed perfectly at home. The large number of trees located by Mr. Dunn vary in age from about 20 to 40 years and in height from 35 to 72 feet, with diameters ranging from 15 to 25 inches. According to Elwes and Henry (The Trees of Great Britain and Ireland, II, 236, 237, 1907, under "Tsuga albertiana") the largest tree in England is said to have been planted in 1856, and in 1907 was 94½ feet high and about 33 inches in diameter. Western hemlock is said to thrive also in temperate parts of Europe. A trial of this hemlock is being made at the Letchworth Park Forest and Arboretum, Wyoming County, N. Y. Seedlings raised from seed planted there in 1914 have survived two winters and appear to be hardy.

[21] The German dendrologist Beissner has described (Handb. Nadelh., 404, 1891) a garden form of the western hemlock as "Tsuga mertensiana macrophylla," which he distinguished by its longer and broader leaves. This form, which originated in France, appears not to be cultivated in the United States. Owing to the fact that a similar broad-leafed form of our eastern hemlock (*Tsuga canadensis*) was previously named "macrophylla," this garden form of the western hemlock was renamed Tsuga heterophylla latifolia Sudw. in 1898. Another garden form, with silvery-white young shoots, doubtless originated in a European nursery, and as yet unknown in cultivation here is "Tsuga mertensiana argenteo-variegata Hort." (Beissner, op. cit., ed. 2, 94, 1909).

The small, few-scaled cones (Pl. IV), which nod from the tips of branchlets, mature from the middle to the end of August. Their scales open rapidly afterwards and usually shed the small, winged seeds during September, or occasionally somewhat later. By spring most of the cones have fallen from the trees. Mature cones are from about three-fourths of an inch to sometimes nearly 1¼ inches long, and of a reddish clay-brown color. The cone scales, peculiar in being sharply narrowed from about their middle, are faintly downy on their outer surfaces. The seeds (Pl. IV, *a*) are light brown. The comparatively large-winged seeds are easily borne by the wind to a considerable distance from the parent tree. Seed-leaves, which vary in number from 3 to 4, are about one-fourth of an inch long. By the third year, seedlings produce foliage like that of the adult tree (Pl. IV, *b*).

Western hemlock wood is narrow-ringed and of a pale yellowish brown color, with a slight tinge of red. It is rather soft ("works" like soft pine), and in texture is very unlike the slivery wood of its eastern relative, Tsuga canadensis, which it otherwise resembles. It is the heaviest of our native hemlocks, a cubic foot of dry wood weighing about 32 pounds. The unfounded prejudice, still existing to some extent, against western hemlock wood is exceedingly unfortunate, because the best grades of this wood are useful for many of the commercial purposes for which pine is used, while the bark of western hemlock yields a much higher percentage of tannin than that of the eastern hemlock (*Tsuga canadensis*), so long and extensively used for tanning leather.

OCCURRENCE AND HABITS.

Tsuga heterophylla is a tree of the middle, moist forest zone, growing from sea level to 7,000 feet elevation (Map No. 4). It is more abundant on the west slopes of mountains than on the east slopes, being absent from the dry inland basins of Oregon, Washington, and British Columbia, but reappearing on the west slope of the Rocky Mountains. The largest trees occur on lower slopes, flats, stream bottoms, etc., on the west slope of the Cascade Mountains and on the coast ranges of Washington and British Columbia. It grows at higher elevations at the south in Washington, Oregon, and California than it does toward its northern limit in Alaska. Likewise, it occurs at lower elevations on the coast mountains than in the Cascades and on the west slope of the Rockies. With abundant atmospheric and soil moisture, western hemlock thrives in poor, thin soils and on any exposure, but it grows best on deep, porous, moist soils. Quality of the soil and exposure become much more important with a decrease in moisture. In dryish poor soils, it seeks chiefly cooler, northern aspects. Lack of soil and moisture produces stunted growth, as do also high elevations, even when abundant moisture and good soils are present.

Western hemlock is usually a subordinate species in association with other trees; but sometimes forms the dominant growth, especially in its far northwestern range, where occasional pure stands also occur. Generally it is scattered in patches, groups, or singly through the forest. From the Pacific coast to the Rocky Mountains its common associates are Alaska cypress (Pacific region), Douglas fir, western red cedar, lowland white fir, silver fir (Pacific region), western white pine, Engelmann spruce, lodgepole pine, and western yew. It is occasionally associated with mountain hemlock.

Tsuga heterophylla is extremely tolerant of shade throughout its life, especially during the seedling stages. In later life, however, vertical light is necessary for the best growth. Prolonged suppression in dense shade greatly checks growth; but when overhead light is admitted, the trees recover remarkably well from long suppression and soon increase their rate of growth. Western hemlock maintains dense stands when growing alone, subordinate to others, or as the dominating tree with equally tolerant or slow-growing species. The ability of this tree to grow throughout its life in the densest shade explains the often almost pure stands that have followed the removal of the older forest in which hemlock was widely but only sparingly represented. The hemlock seedlings had covered the shaded ground in this older forest, and later excluded other less tolerant species trying to come in after the old trees were removed.

Western hemlock is a very prolific seeder, reproducing itself freely everywhere under favorable conditions. Trees 25 to 30 years old may begin to bear seed. Some seed is produced every year, but heavy seed years occur at irregular intervals of from two to three years. The seed has only a moderate rate of germination and fairly persistent vitality. Germination is excellent and growth of seedlings good on wet moss, humus, litter, decaying wood, muck, and mineral soils, the latter being less favorable than a seed bed of moist vegetable matter. In the dense, moist forests in which this tree grows best, its numerous seedlings are a familiar sight on moss-covered stumps and logs—often lodged high in the air—and even in the moss on living trunks. Not infrequently seedlings extend their roots through or over these decaying stumps or logs into the soil and become firmly rooted; many others, unable to do this, die.[22] Reproduction occurs abundantly under the dense shade of mature stands and also in the open on cut-over areas where the forest floor is moist. Burned-over areas, as a rule, are restocked only sparingly at first by this species, because such light-demanding trees as Douglas fir, pine, larch, fir, etc., come in first.

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[22] Mr. F. H. Conant, of Auburn, Wash., an old timber cruiser, says in a letter to the writer under date of Feb. 12, 1909, that during logging operations in (sec. 15, T. 21 N., R. 8 E.) west Washington a 240-year-old western hemlock was cut that had grown upon the prostrate trunk of an old Douglas fir.

LONGEVITY.

Western hemlock is a long-lived tree, which grows slowly in height and diameter. Trees 16 or 17 inches in diameter are from 195 to 200 years old. Large trees are from 300 to 500 years old, and it is believed that very much older trees will be found.

MOUNTAIN HEMLOCK; BLACK HEMLOCK.

Tsuga mertensiana (Bong.) Sargent.

COMMON NAME AND EARLY HISTORY.

Tsuga mertensiana is known to few people except botanists and woodsmen who travel in its high mountain habitat. The woodsmen and settlers often call it "spruce hemlock," probably because of its remote resemblance to the spruces and likeness to the well-known western hemlock of lower altitudes. "Black hemlock" is a common name often applied to it, probably on account of the notably dark green foliage. "Mountain hemlock" would seem to be a most appropriate name for this species, because it refers to the characteristic habitat of the tree.[23]

Tsuga mertensiana was first discovered in 1827 on Baranoff Island (off the northwest coast of British Columbia) by the German explorer and naturalist, Karl Heinrich Mertens,[24] in honor of whom this species was technically named for the first time "Pinus mertensiana Bongard" in 1832, and on which the present accepted name, Tsuga mertensiana (Bong.) Sargent, is based. It was next found in 1851 by John Jeffrey "on the Mount Baker range of mountains" (south of Fraser River) in northern Washington.[25] Mountain hemlock was found for the first time in our Rocky Mountain region by Dr. Sereno Watson, who discovered it in Idaho, in 1880. Mr. H. B. Ayres next reported it in northern Montana, in 1893.[26] The botanical history of mountain hemlock is complicated by a large synonymy including some sixteen different botanical names which various authors have applied to it during the 80 years this tree has been known to

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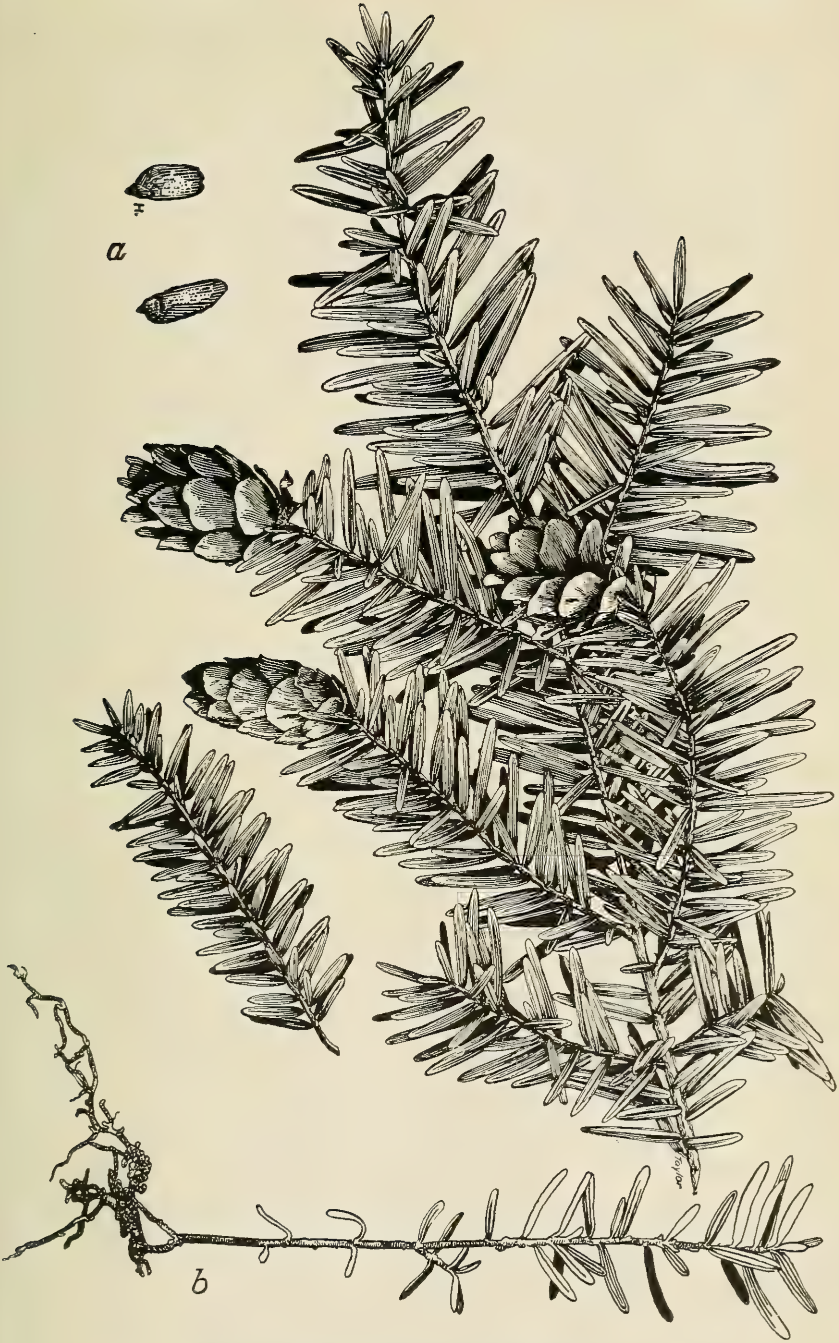
[23] The application in 1867 of the technical names "Tsuga pattoniana Sénéc." (based on "Abies pattoniana Balf.," published in 1853), and of "Tsuga hookeriana Carr." (based on "Abies hookeriana Murray," published in 1855), gave rise to such book names as "Patton's spruce" and "Hooker's hemlock," which are still maintained for this tree by European writers, but which have not gained current use in the native range of the species.

[24] "Voyage autour du Monde exécuté par ordre de sa Majesté l'Empereur Nicolas I. sur La Carvette Le Sémiavine dans les Années, 1826, 1828 et 1829, par Frédéric Lutki," III, 337 (fide Sargent, Silva XII, 80, 1898).

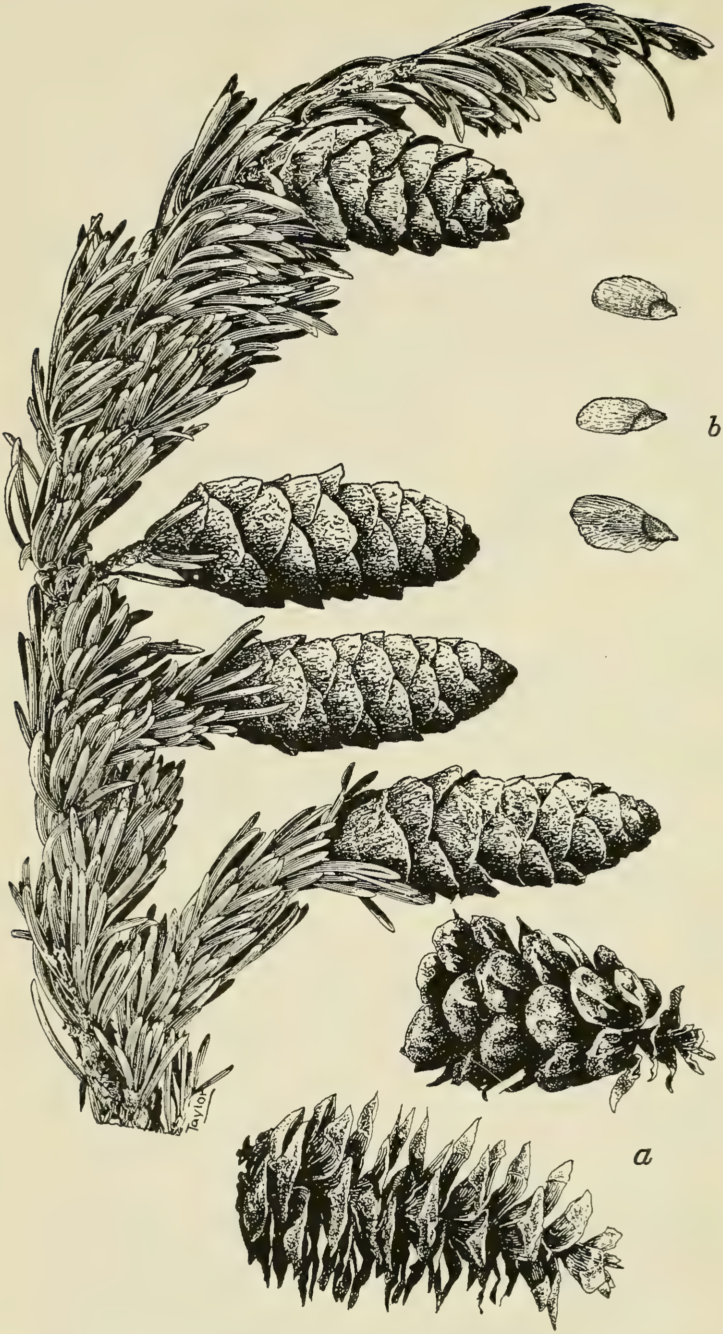
[25] "Jeffrey's Report to the Oregon Committee," 1852.

[26] Fide Sargent, Silva XII, 79, 1898.



TSUGA HETEROPHYLLA: FOLIAGE AND OPEN CONES.

a, Seeds with wings; *b*, seedling 3 years old.



TSUGA MERTENSIANA: FOLIAGE AND CLOSED CONES.

a, Detached open cones; *b*, seeds with wings.

science. From 1867 to 1898 mountain hemlock was known to most botanists as "Tsuga pattoniana Sénéclauze," at the close of which period Prof. C. S. Sargent showed Tsuga mertensiana to be the correct designation.[27]

DISTINGUISHING CHARACTERISTICS.

Mountain hemlock has little general resemblance to the better-known western hemlock. Only its drooping slender branches and its bark suggest hemlock to the casual observer, by whom its foliage might be easily mistaken for that of a spruce or, possibly, of a fir. Forest-grown trees have sharp-pointed, narrowly pyramidal crowns of slender, conspicuously drooping branches; the upper third of the crown has very short drooping branches, while the exceedingly slender whiplike leaders are gracefully pendulous. Trees grown in the open bear branches of the same habit down to the ground, rarely losing them for more than a few feet above ground, even in old age. Ordinarily, mountain hemlock is short, from 25 to 60 feet high and from 10 to 20 inches in diameter; on bleak crests, it is only a few feet high or sprawling on the ground. Trees 75 or 80 feet high are not uncommon, while trees 100 or 150 feet high, with a diameter of 30 or 40 inches, are sometimes met with. The trunk is often rather sharply tapering. On high steep slopes the trunks have a conspicuous bend at the base in the form of a sled runner. This is produced by heavy snows which annually bend or crush the slender seedlings and saplings to the ground without killing them. Later growth fails to straighten entirely the bent stems. The bark is early broken and rough on young trees. That of old trees is about 1¼ inches thick and of a dull purplish to dark reddish brown color. It is deeply and narrowly furrowed, the rough, hard, distantly connected ridges being narrow and rounded. At some distance the trunks have a blue-gray tinge.

The dense foliage varies from a dark to a pale blue-green. Foliage of a season's growth is shed about the fourth year. The blunt-pointed leaves (Pl. V) are rounded and plump looking, being unlike the flat, grooved leaves of other hemlocks in this respect, but like them in having small distinct stems. The leaves clothe the branches all around, but appear thicker on their upper sides. The main branchlets are unique in having numerous short, erect side twigs; both are minutely downy for several years.

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[27] Mountain hemlock is said to have been first introduced into cultivation in Scotland from seeds collected by John Jeffrey "on the Mount Baker range of mountains" in 1851 (Murray, Edin. New. Phil. Journ., 289, 1855; Proc. Hort. Soc. II, 202, 1863). The bluish-leafed form of this tree cultivated for ornament in European gardens has been named "Tsuga pattoniana argentea Beissner" (Handb. Nadelh., 410, 1891), this name being changed to "Tsuga mertensiana argentea (Beissn.) Sudw." in 1898. Elwes and Henry (The Trees of Great Britain and Ireland, II, 231, 1907) have distinguished a garden form with "greenish foliage" as "Tsuga pattoniana, var. Jeffreyi," stating that it is known only in cultivation.

The cones become full grown in one season. They are usually so abundant as almost to cover the branchlets and to bend them down with their weight. When mature the cones are pendulous; very rarely, and then chiefly on stunted trees in exposed situations, are they erect when mature. They vary greatly in length from about one-half an inch to 3 inches; commonly, they are about 2 inches long and three-fourths of an inch thick before opening (Pl. V). There is great variation in the color of cones at maturity, this ranging from yellowish green to a bluish purple. Different trees of the same forest may each have differently colored mature cones; but the color is a transient characteristic and there is no other difference between such trees. When the cones open, and for some time afterwards, they are of a dull to light brown color, the scales spreading at right angles to the cone axis (Pl. V, *a*) or being strongly bent downward. After the seeds are shed, usually late in September or October, the cones begin falling from the trees, and by spring most of them are down. The pale brown seeds (Pl. V, *b*) are provided with large wings which enable the wind to carry them for long distances. Seed-leaves of the mountain hemlock are four in number, and about one-fourth of an inch in length.

The wood of mountain hemlock is very narrow-ringed, soft, and of a pale reddish brown color. It is without the silvery character peculiar to our eastern hemlock wood. It ranks second in weight among our native hemlocks, a cubic foot of dry wood weighing about 27¾ pounds. It is practically never used for commercial purposes, and locally only occasionally on the prospector's camp fire or for his rough-log cabin.

OCCURRENCE AND HABITS.

Tsuga mertensiana grows mainly at timber line, but far north in the Pacific region it occurs at sea level. Southward in the Pacific region and eastward in the Rockies (Map No. 5) its vertical range is determined by the gradual ascent of favorable climatic and moisture conditions, which for these regions confine the tree to high, cold, moist, mountain slopes and valleys. It thrives in most well-drained soils which are not too dry, but best in loose, coarse, moist ones, at elevations ranging from sea level to about 11,000 feet. The highest elevation attained is in the California Sierras. So far as is now known, its vertical range in the Rocky Mountains is between about 5,500 and 8,000 feet, or occasionally up to 9,000 feet.

The best stands occur on flats, gentle slopes, and at the heads of moist valleys, or in sheltered ravines. It has a decided preference for north exposures, doubtless because it encounters less heat and greater soil moisture there. Although often abundant on exposed high slopes, it is usually stunted in such situations, which are least favorable to the best growth. At high altitudes, mountain hemlock occurs very commonly in small pure stands and also in mixture with white-bark pine, alpine fir, alpine larch, and Engelmann spruce, while lowland white fir, lodgepole pine, and western white pine are occasional associates at lower elevations. Large pure stands are uncommon, but rather extensive mixed forests are occasionally found containing as much as 85 per cent of this hemlock.

Mountain hemlock is very tolerant of shade, surpassing all of its associates, except western hemlock, in shade endurance. Its dense shade, which in some instances almost excludes light from the ground, usually prevents growth of all seedlings, even of its own, which appear to require more light than is available under the mother trees, but which thrive under lodgepole pine, fir, etc. Seedlings grow more thriftily in moderate shade than in full light. Seedlings and saplings bear long suppression, rarely dying under it, and resume normal growth when top light is admitted. Because of the mountain hemlock's great shade-enduring qualities, the trunks are not readily cleared of branches, even in dense stands. The branches become so large before they die that they usually persist for a long time or leave short stubs, thus forming loose knots in timber.

Tsuga mertensiana is a prolific seeder, some trees beginning to produce cones when about 20 years old. More or less seed is borne annually, but good seed years occur only at intervals of several years. The seed has only a moderate rate of germination, and its vitality is rather transient. With sufficient moisture, seed germinates on both humus and mineral soils, but much more readily on the latter.

LONGEVITY.

The age limit of mountain hemlock is not known at present, but it is believed to be a very long-lived tree, probably attaining an age of from 400 to 500 years. Trees from 18 to 20 inches in diameter are from 180 to 260 years old, while trees only from 5 to 7 inches in diameter growing on high, wind-swept ridges are from 60 to 80 years old.

GENERIC CHARACTERISTICS OF FALSE HEMLOCKS.

The generic name Pseudotsuga, false hemlocks, is applied to a group of trees related to the hemlocks (*Tsuga*), which they resemble in the contracted base of their leaves and in the habit and character of their cones. The resin vesicles peculiar to hemlock seeds, are, however, absent from the seeds of Pseudotsugas. Like the balsam fir trees, the false hemlocks have small resin pockets, or "blisters," in the bark of young trunks and branches. Woodsmen and lumbermen know the trees of this group as "varieties" of "fir" or "spruce," and even as "pines," this being due probably to the superficial resemblance of the wood to that of spruces and pines.

Obviously, however, use of the name pine for these trees is a perversion, for in all respects the pines are totally different trees. Properly, moreover, they should not be called firs, from which they differ greatly in the character of their wood, foliage, and cones.

False hemlocks are evergreen trees with dense, soft, foliage. Their branches, which grow from the trunks in irregular circles, form, with their many side branches, wide fanlike sprays. The rough, thick-barked gradually tapered trunks are tall, straight, and, in the case of one species, very massive. They have broadly pyramidal crowns, which in the case of young trees extend down to the ground.

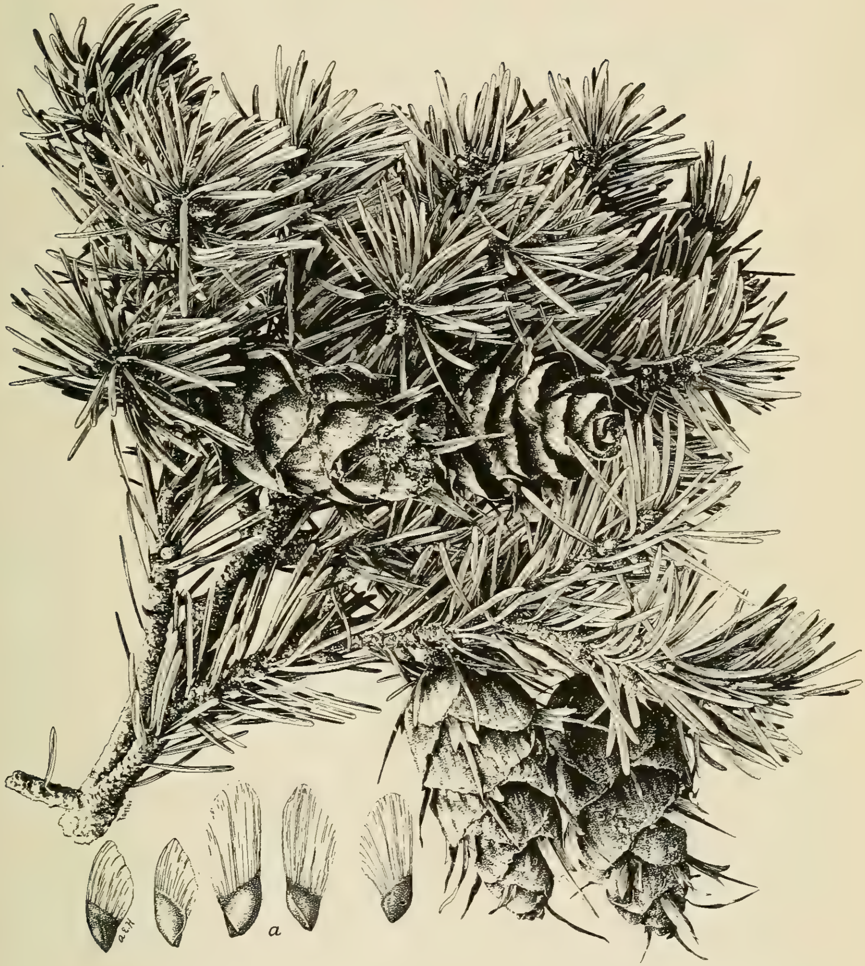
The flat, bluntish leaves, with contracted bases, are single and spirally arranged on the twigs and branches. They appear often to grow mainly from two opposite sides and from the top of the branches, but by a twist in their stems the lower leaves are bent upward toward each side of the branch. Leaves of a season's growth remain on the tree from about five to eight years. In cross section the leaves show two resin ducts situated near the edge on the underside.

The male and female flowers are each borne singly on different parts of the same tree, the twigs on which flowers are borne being formed the previous year. The female flowers, bristly, scaly bodies which develop into cones with seed, are borne nearly or quite at the ends of twigs, while the male flowers, scaly bodies bearing pollen only, grow from the bases of leaves farther back from the ends of the twigs. Most characteristic of the false hemlocks are their pendulous cones with conspicuous 3-pointed, scalelike bracts, which protrude from among the cone scales (Pl. VI). None of our other native evergreen-leafed conifers that bear cones with persistent cone scales produce exserted bracts. The thin-scaled cones mature in one season, soon afterwards falling from the trees. Two-winged seeds (Pl. VI, *a*) are borne under each cone scale. Their large, light wings permit the wind to distribute them easily. The seed-leaves of Pseudotsuga are flat and vary in number from 6 to 12, being commonly 6.

The trees of this group are of the greatest commercial importance (mainly one species), supplying great quantities of the finest and largest saw timber of any of our native trees, if not of any trees in the world. The slightly resinous, pinelike wood is suitable for all sorts of construction purposes.

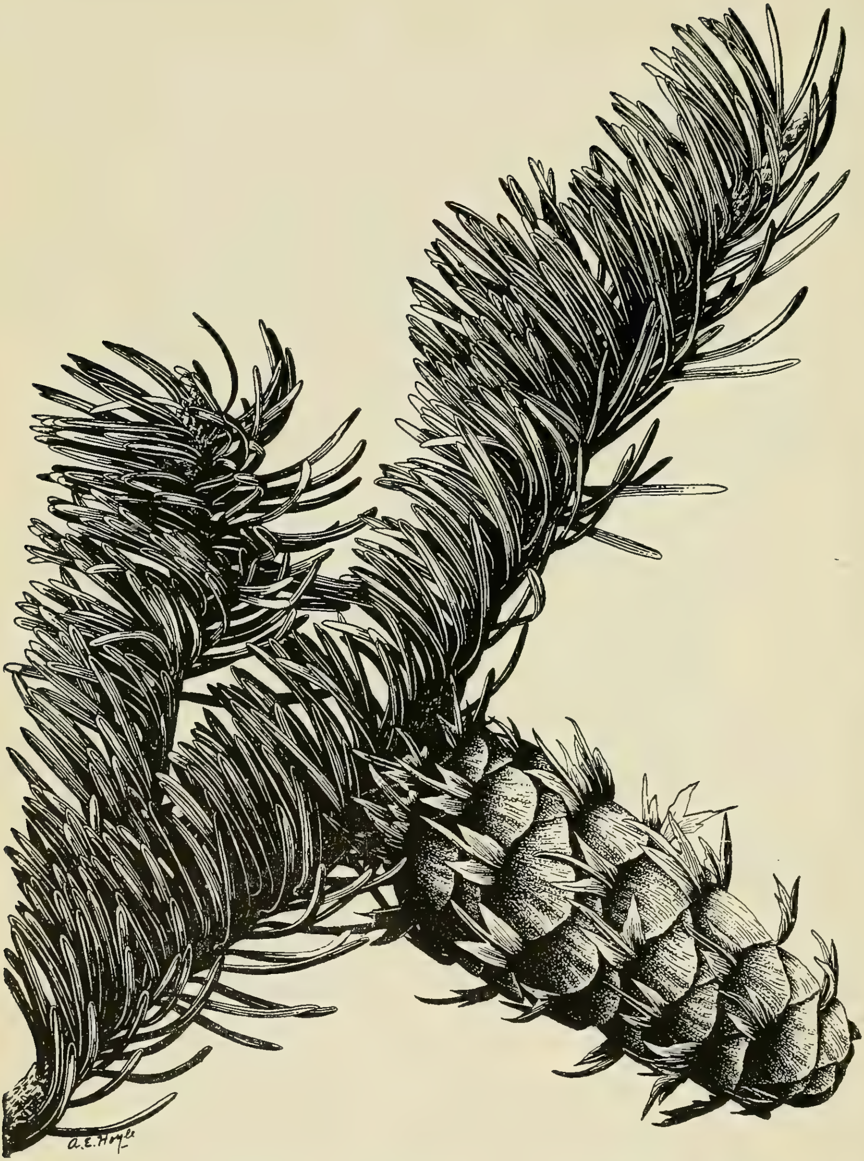
Two species of this group are natives of North America. One is distributed more or less from the Rocky Mountain States to the Pacific coast, extending also into adjacent Canadian and Mexican territory, while the other species inhabits the mountains of southern California.

Species of this genus are of ancient origin, the wood of some of them having been found in the Middle Tertiary period of western Canada, while remains of Pseudotsuga taxifolia occur in the Pleistocene of



PSEUDOTSUGA TAXIFOLIA: FOLIAGE AND OPEN CONES.

a. Upper and lower sides of seeds with wings, showing variation in size of wings.



PSEUDOTSUGA TAXIFOLIA: FOLIAGE AND OPEN CONE.

Montana, and those of Pseudotsuga macrocarpa in the Pleistocene of Humboldt County, Cal.[28]

DOUGLAS FIR; DOUGLAS SPRUCE.

Pseudotsuga taxifolia (Poir.) Britton.

COMMON NAME AND EARLY HISTORY.

During the last 30 years Pseudotsuga taxifolia has become very widely known both in this country and elsewhere for its commercially valuable timber. Many confusing common names, such as "red fir," "red spruce," "Douglas spruce," "yellow fir," "Oregon pine," and "Puget Sound pine," have been applied to it in different parts of its extensive range, but it is now generally known as Douglas fir, which commemorates the name of David Douglas, by whom seed of this tree was first sent to England[29] in 1827 from the region of Columbia River, Oreg. Through this seed the tree first became known to science. The tree was, however, first discovered in 1791 by Dr. Archibald Menzies, who found it on Nootka Sound (west coast of Vancouver Island). Dr. Menzies was at that time a surgeon attached to George Vancouver's expedition[30] to the north Pacific coast. Lewis and Clark's[31] account of this tree, published in 1805, was the first printed notice of it to appear. Dr. C. C. Parry's discovery of Douglas fir in the Rockies of Colorado in 1862 is the first instance of its being found east of the Pacific slope.

The botanical history of Douglas fir shows that nearly 30 specific and varietal names have been applied to the tree during the 113 years it has been known to science.[32] The first tenable

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[28] Fide Dr. Edward W. Berry. See footnote 4.

[29] Fide J. G. Jack, in Garden and Forest, VI, 14, 1893.

[30] See footnote 19.

[31] History of expedition under command of Lewis and Clark, III, 831 (ed. Coues), 1805.

[32] Douglas fir is said to have been first introduced into cultivation in England from the Pacific region in about 1827. A tree at Dropmore, raised from seed planted at that time, is believed to be the oldest one in England (Frost. in Gard. Chron. 1871, p. 1360).

According to Elwes and Henry (The Trees of Great Britain and Ireland, IV, 824-827, 1909), trials in England of the Rocky Mountain and Pacific slope forms of Douglas fir show that both grow well there, but that trees from the Pacific region grow considerably faster and are, therefore, much more desirable for forest planting there than the Rocky Mountain form.

A number of the largest trees in England planted during the period from about 1830 to 1865 range from about 100 to 128 feet in height and from 4 to 6 feet in diameter.

As nearly as can be determined, Douglas fir was first introduced into cultivation in Europe in 1831. John Booth (Die Douglas Fichte u. e. a. Nadelh., 50, 1877) speaks of the record of a tree 2 years old planted in Germany during that year as the oldest example known there in 1877. This tree was then 48 years old and about 70 feet high, with a diameter of 22 inches. Booth mentions having seen another tree of similar proportions, probably planted at about the same time in the region of Greifswald, Germany, and also one planted near Bremen in 1855, which was 39½ feet high in 1877. It is not known whether or not these trees are the Pacific slope or the Rocky Mountain form.

Extensive tests made by the German Government during the early nineties of both the Pacific slope and the Rocky Mountain forms of Douglas fir show that the former strain grows more rapidly in Germany than the latter, but that the Pacific slope tree is likely to be injured, though not seriously, by early frost, while the Rocky Mountain form is not affected by low temperatures. Because the Pacific slope, or green-leafed, tree produces the better quality of timber, this form appears to be preferred as a forest tree scientific name applied to Douglas fir is "Abies taxifolia Poiret," published in 1804, on which the present acceptable name, Pseudotsuga taxifolia (Poir.) Britton[33], is based. From 1833 to 1889, the date on which the latter name was established, Douglas fir was known to many botanists as "Abies Douglasii Lindl.," and from 1867 to 1889, as "Pseudotsuga Douglasii, Carrière."

Some 22 different garden varieties of Douglas fir have been named, most of which are distinguished by the size, form of crown, color and shape of leaves, and habit of the branches.[34]

DISTINGUISHING CHARACTERISTICS.

Excepting the great sequoias of California, Douglas fir is the most gigantic tree of our western forests. Under the best conditions for growth, which exist chiefly in the northwest Pacific coast country, it ordinarily reaches 180 or 190 feet in height and from 3½ to 6 feet in diameter. Exceptionally large trees occasionally found are from 200 to 330 feet high and from 8 to 10 feet in diameter.[35] Under less favorable conditions, such as prevail in the range of Douglas fir outside of the humid Pacific coast region (Map No. 6), it commonly attains a height of from 75 to 125 feet and a diameter of from 24 to 40 inches, while in high, exposed situations it is much smaller or greatly stunted, sometimes under 3 feet in height.

The typical crown form of young trees is an open, broad, sharp-pointed pyramid; the lower branches are straight or somewhat

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by a number of German authorities. Others, however, recommend using the Rocky Mountain form because of its greater hardiness.

The first introduction of Douglas fir in eastern United States dates from 1863, when Dr. C. C. Parry is said to have sent seeds of the Rocky Mountain form to the botanic garden of Harvard College. Trees raised from this seed grew thriftily and have proved well adapted to the climate of New England. Later numerous plantings of Douglas fir from its Rocky Mountain range have established the perfect adaptability of the species to our Northeastern States, specimens of it growing fairly well even as far south as the District of Columbia. Douglas fir from the moist climate of its Pacific range does not, as a rule, grow well in our Eastern States.

A number of writers on American trees have maintained that the Pacific slope and the Rocky Mountain forms of this tree are distinct species, this view being based on the common occurrence in the Rockies of blue-leafed trees with the bracts of the cones often reflexed, and of green-leafed trees in the Pacific region with the bracts of the cones usually straight. The decidedly more thrifty growth in Europe and in eastern United States of the Rocky Mountain form, as compared with that of the Pacific slope tree also seemed to indicate specific distinction between these two regional forms. Broadly considered, however, the trees of these regions can not be maintained as distinct species, for the characteristics offered to distinguish them are not dependable, the real difference between them appearing to be wholly of a silvical nature.

[33] Several authors maintain for this tree the name Pseudotsuga mucronata (Raf.) Sudworth, which the writer believes to be lawfully antedated by P. taxifolia (Poir.) Britt. For a full discussion of the basis of this decision, see Bull. 17, Div. For., 23, 1898.

[34] The most distinct and best known of these forms is P. taxifolia pendula (Engelm.) Sudw. and P. taxifolia glauca (Beissn.) Sudw. (Other varieties are listed in Bulletin 17 of the Forest Service, "Check List of the Forest Trees of the United States," 24, 1898, and described by Beissner in his Handbuch der Nadelholz-Kunde, ed. 2, 106, 1909).

[35] In a letter dated Nov. 26, 1912, Mr. Bartle F. Harvey of 265½ Fifth street, Portland, Oreg., called the writer's attention to a Douglas fir tree 14 feet in diameter and 200 feet high, this tree being located about 175 feet from the Tacoma & Eastern Railroad at a point about 2 miles south of the town of Mineral, Pierce County, Wash. The tree is on the tourists' route to Mount Rainier and is visited annually by many people.

drooping and the middle and higher ones trend upward. All of the branches have numerous long, hanging, side branchlets, which are sometimes very long. In dense stands, one-half or two-thirds of the lower branches are shaded out by the time the trees are 10 or 15 inches in diameter. Under these conditions the crowns of middle-aged and old trees lose much of their earlier pyramidal form and become rounded or flattened.

The massive trunks, clear of branches for 80 or 100 feet (in the Pacific region) are straight and taper only slightly. The ashy brown bark of young trees, often with chalky patches, is thin and smooth and but little broken or furrowed, except near the ground, until the trees are from 12 to 14 inches in diameter. Old trees have bark from 5 to 10 inches thick at the base of the trunk, although higher up it is much thinner. Very old trees sometimes have bark from 18 to 24 inches thick. The bark is of a dark brown color outside and a clear red-brown within. It is often very rough, with deep, wide furrows and great ridges, which are connected at intervals by narrower diagonally disposed cross ridges. There is great variation in the character and markings of the bark in dry and humid regions, and also on trees in exposed and protected situations. In exposed, dry situations, such as are common in the southern and middle Rockies, trees have rougher and harder bark than in the moist, dense forest of the Pacific region. Moreover, trees of the high, very dry interior Rocky Mountain slopes, particularly young trees, may have soft, corklike,[36] gray-brown bark. This may well be a result of the excessively dry atmosphere, for one or two balsam firs of that region have similar bark. In other characteristics, however, these trees do not differ from those with the ordinary bark.

Mature foliage is usually a deep yellow-green. In the drier parts of its range, particularly in the Rocky Mountain region, Douglas fir sometimes has blue-grass[37] foliage of varying shades. These blue shades are especially pronounced during the early maturity of the leaves. Each season's growth of leaves remains on the tree about eight years, soon after which it is shed at irregular intervals. The leaves (Pl. VI) are flat, slightly grooved above and commonly blunt, or very occasionally pointed.

The cones (Pls. VI, VII) ripen early in August, and by September they are of cinnamon or reddish brown color. Their scales soon begin to open and shed their seed, the cones dropping from the trees a few weeks later. One of the simplest means of identifying this tree is by the 3-pointed, tridentlike, thin bracts[38] protruding from among the cone scales. Cones vary in length from 1½ to 4½ inches, but commonly from about 2½ to 3 inches. The seeds (Pl. VI, *a*) are dull russet-brown, with areas of white. Seed-leaves, about three-fourths of an inch long, vary in number from 6 to 7 (Pl. VIII).

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[36] The variety "Pseudotsuga taxifolia suberosa Engelmann" is a form of Douglas fir with bark of this character.

[37] About 20 or more different garden varieties and other forms of this tree now distinguished in cultivation are based on color of the foliage and similar individual characteristics.

The wood of Douglas fir varies greatly in quality and in the thickness of annual rings, which may be very wide, medium wide, or narrow. Wide-ringed wood is usually a distinctly reddish brown, this being the "red fir" of lumbermen. Narrow-ringed wood is usually a clear yellowish brown, the "yellow fir" and "Oregon pine" of lumbermen. The botanical characteristics of trees furnishing these dissimilar qualities of wood are the same, and there is no foundation for the popular belief that the woods come from two different "varieties" or "species" of trees; indeed, the two grades of wood may sometimes be obtained from the same tree, the wide-ringed wood being in the center of the trunk and the narrow-ringed wood in the outside portion. For the first 50 to 100 years or more diameter growth is rapid, giving wide-ringed wood ("red fir"), while the later stages of growth are, as a rule, slower and give narrow-ringed wood ("yellow fir"). The invariable difference in color between these two grades of wood is often attributed to the character of the soil, but this explanation ignores the fact that both grades may come from the same tree. Grades intermediate between these are also common, especially in trees grown outside of the humid northwestern range, from which the bulk of "red" and "yellow" timber is obtained. Both grades are exceedingly important commercially, but the narrow-ringed, yellow wood is the more valuable, being extensively used at the present time for the finest sorts of finishing lumber, for which it competes with high-class pine. Douglas fir wood compares closely in weight and texture with western yellow pine, a cubic foot of thoroughly seasoned fir wood weighing about 32 pounds. The yellow-wooded form is much more durable when exposed to the weather or earth than the red-wooded form, the lasting qualities of both grades being rather remarkable when they are used for piling.[39]

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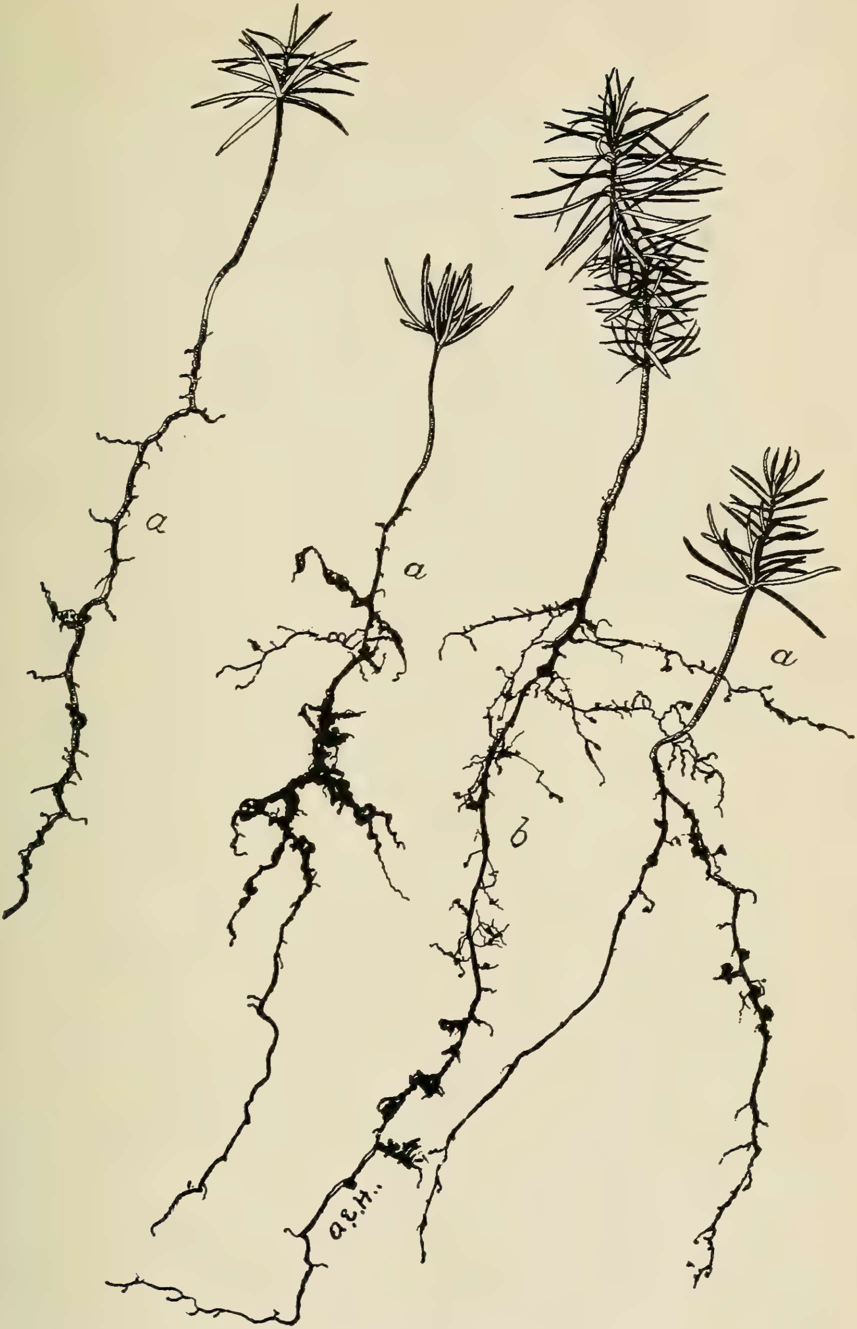
[38] As a rule, the bracts of the Rocky Mountain form of Douglas fir are strongly reflexed (Pl. VII), those of the Pacific slope tree remaining more or less straight (Pl. VI). The latter peculiarity is, however, confined wholly to the more western form of this tree.

[39] In a letter to the writer, dated February 12, 1909, Mr. F. H. Conant says that during lumber operations in (sec. 15, T. 21 N., R. 8 E.) west Washington, two sound logs were cut from a large fallen Douglas fir on the top section of which (then decayed) a 240-year-old western hemlock (cut at that time) had grown. The inference that two sound logs were obtained from the fallen Douglas fir after all those years seems scarcely credible.



PSEUDOTSUGA TAXIFOLIA: SEEDLINGS.

a, 1 year old; *b*, 2 years old.

OCCURRENCE AND HABITS.

In the Rocky Mountain region Douglas fir occurs generally at elevations between about 4,000 and 11,000 feet, the lower elevations being at the North, while in the central and southern Rockies the altitudes attained are from about 6,000 to 11,000 feet (Map No. 6). In the northern Pacific coast country it occurs at sea level. It grows best and in greatest abundance where precipitation and relative humidity of the air are greatest. Except at high elevations and at the northern limit of range, Douglas fir prefers northern to southern exposures, and sheltered slopes, canyons, benches, etc., to exposed situations. At the North, and at high elevations, warmer southern exposures are preferred, for heat, not moisture, then becomes the controlling factor in its growth. The lower limit of vertical range in drier regions is determined by lack of moisture, and the upper limit of distribution is marked chiefly by lack of heat. Douglas fir occurs at higher levels on the east sides of mountains than on the west sides, higher elevations also being reached on southern slopes than on northern exposures. But it is more abundant on western slopes than on eastern slopes, and likewise more frequent on northern than on southern exposures—except at the far North, where heat is the essential factor.

Douglas fir is adapted to a great variety of soils, including nearly all with sufficient moisture, from the border of brackish seacoast water to soils in which, among other trees, only the drought-enduring western yellow pine grows. It prefers fresh, well-drained, porous, deep, loamy soils, avoiding saturated, poorly drained, heavy soils. Good soil and abundant atmospheric and soil moisture are necessary for the best growth, but with abundant moisture, quantity and quality of soil are less important, and vice versa. Douglas fir grows faster and larger on poor gravels and sand in the humid Puget Sound country than on the best soils of the Rocky Mountains, where it is subject to dry air and deficient precipitation; likewise, it is not so large on the best soils of the drier California mountains, even though the climate is mild and heat and sunshine are sufficiently abundant for other tree growth.

Douglas fir forms large pure forests and often nearly pure stands, but chiefly it is associated with a number of other species. In the northern Rocky Mountain region it grows with western white pine, western yellow pine, lodgepole pine, western red cedar, lowland white fir, western hemlock, Engelmann spruce, alpine fir, and western larch. Here the climatic and soil conditions are similar in great measure to those of the northern Pacific slope country, and account for the presence of so many typically west-slope trees. In the middle Rockies, where the climate and soils are dry, Douglas fir is associated more often with lodgepole pine and Englemann spruce, while western yellow pine grows with it at the lower elevations and alpine fir at its upper limits of range. The southern Rockies and adjacent dry interior mountains, into which Douglas fir extends, are characterized by climatic conditions differing greatly from those of the middle and northern parts of this chain of mountains, so that here Douglas fir is variously associated with limber pine, Mexican white pine, bristle-cone pine, Engelmann spruce, white fir, cork fir, Gambel oak, and aspen.

Douglas fir is moderately tolerant of shade in its earlier growth, becoming less so with age. Tolerance, however, varies with the locality and region, being greatest under the conditions productive of the best growth. The tree endures more shade than western yellow pine, sugar pine, western white pine, and lodgepole pine, but less than western hemlock, western red cedar, white and alpine firs, incense cedar, and Engelmann, blue, and Sitka spruces. Partial shade and shelter are very necessary in the early life of Douglas fir wherever the conditions for growth are least favorable. At the North, where moisture is abundant, it thrives in the open from early youth, while in drier interior regions it prefers the shade of weeds, brush, etc. Dense pure or mixed stands in the Northwest have clean trunks for about two-thirds of the length, while trees of open forests and those in the Rocky Mountains are clean-trunked for only about one-third their length, or, in scattered stands, carry branches almost to the ground. The trunks clean themselves of side branches slowly even in dense stands, which indicates considerable tolerance of side shade; on the other hand, young trees in dense stands grow rapidly in height, showing their need of overhead light.

Douglas fir is generally a prolific seeder, producing seed nearly every year, with specially good local seed years at intervals of three or four years. The seed is matured at about the same time throughout the tree's range. Throughout the range of Douglas fir its seed formation is nearly as abundant and its power of reproduction nearly as great as in the case of western yellow pine. At best the seed has a moderately high rate of germination and persistent vitality. Not infrequently, however, the seed has a rather low percentage of germination, which may be due in some measure to the fact that a large number of seeds are destroyed by insects. Many are also eaten by birds and rodents. Germination and early development of seedlings are best on warm, moist, pure mineral soil, or in one mixed with humus. Reproduction is rare on thick duff or vegetable matter, but abundant in humid regions after this layer has been burned off, or thoroughly broken up by logging operations. Unburned, logged areas in this moist region are more commonly restocked by western hemlock and red cedar. In the drier more southern Rocky Mountain range of Douglas fir, burned-over ground is usually unfavorable to reproduction of this species, lodgepole pine, aspen, and other trees usually restocking such areas. Under the most favorable conditions, reproduction of Douglas fir is extremely dense, an acre sometimes carrying over 30,000 trees about 3 feet high and 11 years old, while a stand of 26-year-old trees may average 1,068 per acre, 45 feet high and 3½ inches in diameter.

LONGEVITY.

Douglas fir is a very long-lived tree. Specimens from 3 to 4 feet in diameter are from 150 to 200 years old, while those from 4 to 8 feet in diameter are from 200 to 375 years old. One tree 9 feet through showed an age of 435 years. The ages of rare trees larger than this are probably from 400 to 500 years.[40]

GENERIC CHARACTERISTICS OF INCENSE CEDARS.

Trees of the group Libocedrus are characterized by their conical trunks, thick bark, and the very strong but pleasant odor of their light, soft, straight-grained, durable wood. The branchlets are arranged in one plane, forming flat, fanlike sprays. The twigs of adult trees are clothed with evergreen, scalelike, pointed leaves, which overlap each other closely (Pl. IX *a*, *b*). On the short side branchlets the leaves are much flattened, but on the larger main stems they are rounded. The leaves of each season's growth remain on the tree for about 4 or 5 years. In the case of seedlings the leaves are needlelike, flat, sharp-pointed, and spreading (Pl. X, *b*). As the plants grow older this juvenile form of leaf is succeeded by shorter and less and less spreading ones, until finally the scalelike adult form of foliage is assumed. All of the leaves are arranged in pairs, each pair being placed on the branch at right angles to the preceding pair. The adult leaves also have characteristically long bases, which extend downward, completely covering the branch, a habit on which the technical specific name, decurrens, of our native incense cedar is based. The seed-leaves (first foliar organs produced) are needlelike and flat and usually two in number, or occasionally three (Pl. X, *a*).

Both the male and female flowers are small, inconspicuous, oval or elongated bodies borne at the ends of branchlets produced the previous year, the male flowers being of a yellowish green and the female of a greenish color. They are both formed during the autumn, but they open late during the succeeding winter or in early spring. Flowers of the different sexes are sometimes borne on the same tree, even on different twigs of the same branch, but as a rule they are borne on different trees.

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[40] Mr. F. H. Conant (see footnote 39) states (l. c.) that in secs 9 and 15, T. 21 N., R. 8 E., in west Washington, he counted the annual rings of growth of several trees which proved to be 600 and 700 years old.

The small cones (Pl. IX, *a*) which mature in one season, are composed of 3 pairs of scales (practically of only 2 pairs). The first or basal pair is at the base of the cone; a second pair, the largest, forms most of the cone's body and incloses 1 or 2 winged seeds (Pl. IX, *c*) on each of its scales; the third pair is joined into a central flat, thick, woody wall, upon each face of which one of the preceding seed-bearing scales clasps. The seeds (Pl. IX, *c*) are ripe in early autumn and are shed soon afterwards, their large wings aiding greatly in wide dissemination by the wind. After shedding their seeds some of the cones remain on the trees at least until the succeeding summer.

All of the species of this group, eight in number, are rather large, important forest trees, which produce durable commercially valuable wood. Nearly all of them are long-lived trees. One species only inhabits the United States, this being confined chiefly to our Pacific region. Seven other species are natives of western South America, New Zealand, New Caledonia, and China. The group is further interesting from the fact that in geologic times species related to those now living existed in the upper Cretaceous, Oligocene, and Miocene periods of Europe, as well as farther north in Spitzbergen and Greenland. A well marked species of Libocedrus has been found in the Miocene Lake bed at Florissant, Colo.[41]

INCENSE CEDAR.

Libocedrus decurrens Torrey.

COMMON NAME AND EARLY HISTORY.

Libocedrus decurrens is variously known throughout its range by such common names as incense cedar, post cedar, bastard cedar, and white cedar, none of which is very generally adopted. The name incense cedar is as widely used as any, and would appear to be most preferable because it refers to the incenselike odor of the wood, which is a distinctive feature. The other common names applied to it are undesirable because they are either meaningless or conflict with previously established common names of some other native trees.

Incense cedar is only sparingly represented in the western edge of the Rocky Mountain region (Map No. 7), where it was first discovered in 1871 at a point in the Washoe Mountains above Carson City, Nev. Later (1911) it was again found very near the Nevada line in Alpine County, Cal. Its main range lies in the Pacific slope country, where Capt. John C. Frémont found it in 1846 on the headwaters of the Sacramento River. The first technical name (*Libo-*

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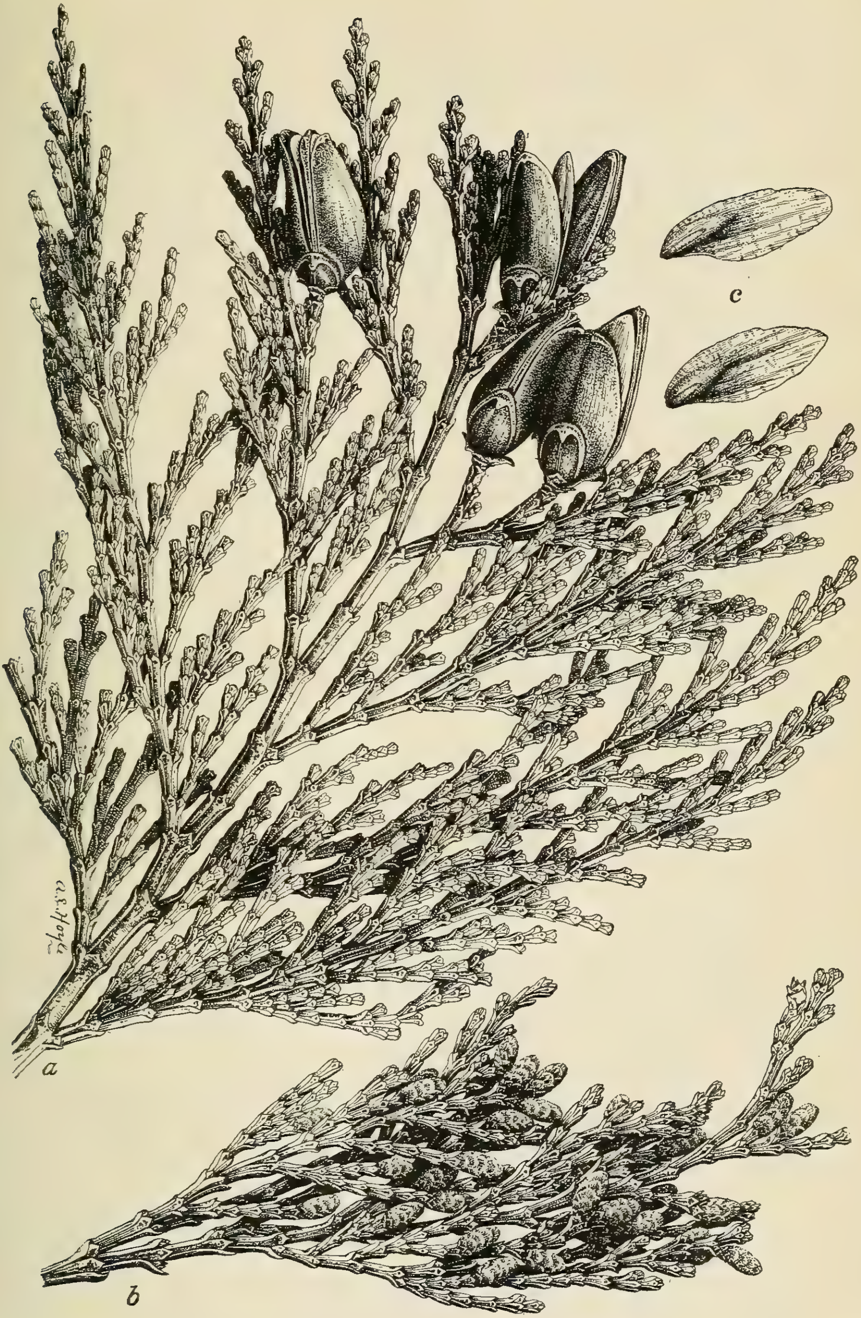
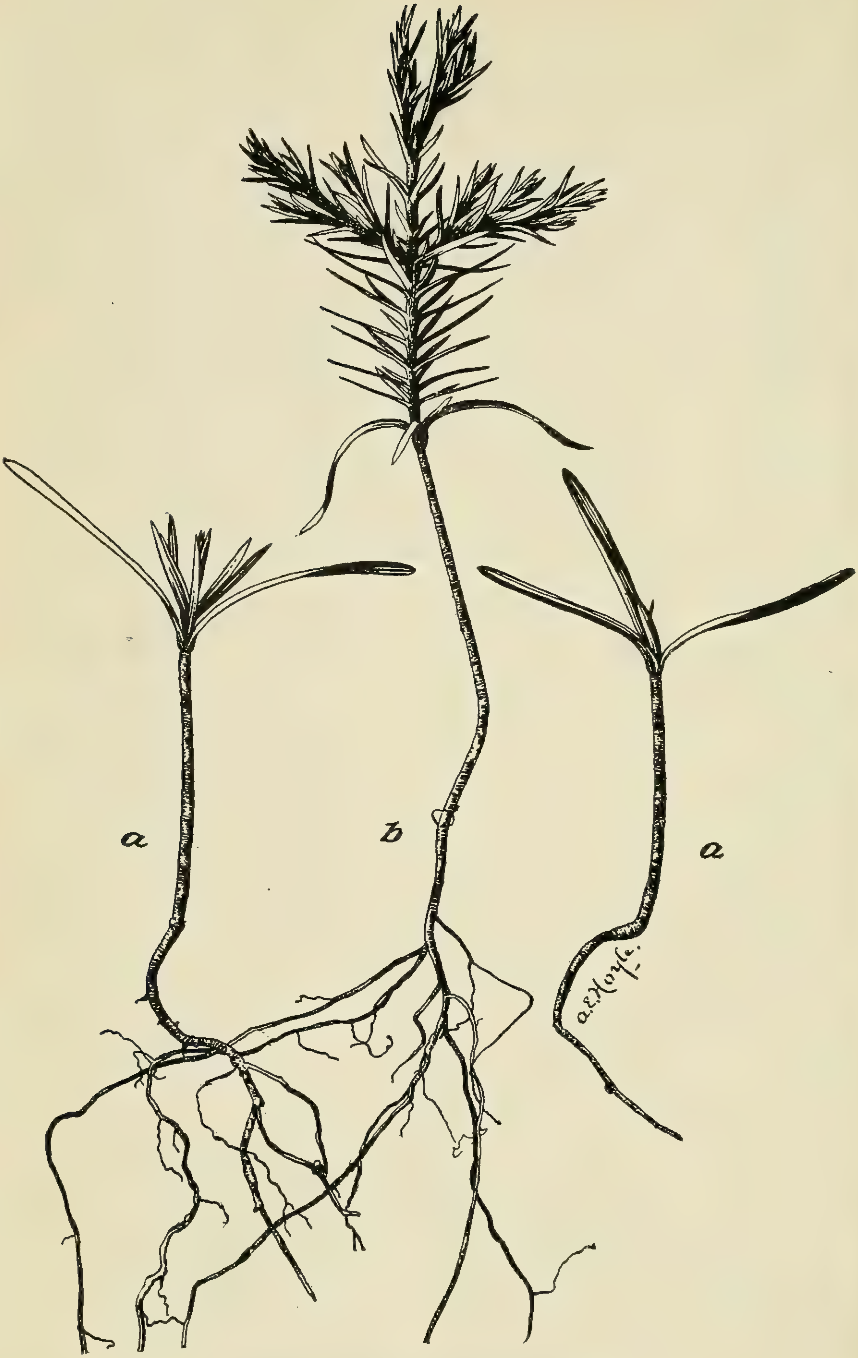
[41] Fide Dr. Edward W. Berry, see footnote 4.

PLATE IX.



LIBOCEDRUS DECURRENS: FOLIAGE AND CONES.

a, Ripe, partly opened cones; *b*, branch with male flowers; *c*, seeds and their wings.



LIBOCEDRUS DECURRENS: SEEDLINGS.

a, 1 month old: *b*, 4 months old.

cedrus decurrens Torr.), applied to this tree was published with its accompanying description, in 1854, and since that time the tree has been known to botanists practically only by this name. The botanical history of Libocedrus decurrens contains little or no confusion with other similar trees, and but three technical names, now synonyms, have been applied to it during the 62 years it has been known to science.[42]

DISTINGUISHING CHARACTERISTICS.

The striking characteristics of old incense cedar trees are their rapidly tapering trunks with widely buttressed bases and their thick, cinnamon-brown, deeply furrowed, and ridged bark. The bark of such trees is from 2 to 3 inches thick, or more, at the base of the trunks, while higher up it is scarcely more than an inch thick. Young trees have thin, smooth, slightly scaly bark of a clear, cinnamon-red color. Mature trees are ordinarily from 80 to 100 feet in height, and from 30 to 50 inches in diameter; exceptionally large trees are from 125 to 160[43] feet in height and from 6 to 8 feet in diameter. The clear length of stem among large trees varies from 40 to 70 feet. The largest size is attained in the Pacific region, trees within the limited Rocky Mountain range rarely exceeding 70 feet in height and 30 inches in diameter.

The crowns of large trees are very open and irregular, consisting of a few short, scattered branches on the upper third of the stem, and sometimes several large, leaderlike top branches, all with dense tufts of light yellow-green foliage. Young trees, up to about 12 inches in diameter, that have grown in full light, carry a pointed, narrow, open, columnar crown, which usually extends down to the ground. At the bottom of the crown the branches are slender and curve down and up at their ends; higher up on the trunk they gradually swing upward more and more toward the narrow-pointed top. Short, flat, drooping sprays of foliage terminate the branches. A notable feature of the branches is that they shed numerous short side twigs, which die in about their second or third year as the main divisions of the branch enlarge. (This is true also of other cedars, particularly Thujas.) The form and habit of the adult and juvenile leaves and of the cones have already been defined in detail under the "Generic Characteristics of Incense Cedars."

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[42] Libocedrus decurrens appears to be very generally planted for ornament in the British Isles, and in west central and southern Europe, where the tree seems to be well adapted for growth. It is said to have been first introduced into cultivation in Scotland in 1853. Elwes and Henry (Trees of Great Britain and Ireland, III, 492, 1908) mention a tree planted there in 1863, which, in 1905, measured 53 feet in height and about 21 inches in diameter. Another tree mentioned, probably the first one grown in England, was planted "about 1850," and in 1907 measured 53 feet in height and about 32 inches in diameter. The largest tree found by these authors in England was planted in 1857, and in 1904 was 64 feet high and 30 inches in diameter. Much larger trees were found in northern Italy, two specimens mentioned by Elwes and Henry (l. c.) each being 90 feet high and 37 and 39 inches in diameter.

Just when Libocedrus decurrens was first cultivated in eastern United States is unknown. It grows well in the middle Atlantic States, but is not hardy north of southern New York. Probably the earliest planting of this species in the East was by Mr. William Saunders, who set several trees in the grounds of the Agricultural Department, at Washington D. C., about 1867, Mr. Saunders then being superintendent of the department grounds. One of these trees, still standing, is now about 30 feet high and 14 inches in diameter.

[43] Probably the largest incense cedars now known are two trees recently reported by the district forester of district 5. The larger in diameter of these trees, located near Morgan Springs, Tehama County, Cal. (in the Lassen National Forest), is 120 feet in height and 8 feet in diameter, and is estimated to contain 9,700 board feet. The taller is located in the Shasta National Forest (California) and measures 161 feet in height and 83 inches in diameter. Since these two records were obtained, Mr. J. Alfred Mitchell reports trees ranging from 162 to 183 feet in height, and one tree, recently cut, that was 186 feet high. (Bul. 604, U. S. Department of Agriculture, pp. 13, 14, 1918.)

The flowers of incense cedar open in midwinter or very early spring (Pl. IX, *b*). Both the male and female flowers are each borne on the ends of separate year-old twigs, either of the same tree and branch or of different trees. The cones (Pl. IX, *a*) are ripe by the middle or latter part of August and usually begin to shed their yellowish brown, large-winged seeds (Pl. IX, *c*) late in September, most of the seed falling by the end of October. When the cones are dry and fully open they are of a reddish brown color and the two large outer cone scales are spread wide apart. Most of the cones fall from the trees during the succeeding winter, but some always adhere to the branches until the following spring or summer. The seeds contain glands with clear red, pungently odorous resin. Seed-leaves, two in number, or occasionally three, are usually blunt or only slightly pointed, and about 1¼ inches in length by almost one-eighth of an inch in width (Pl. X, *a*). The succeeding primary leaves are sharp-pointed and stand out from the stem (Pl. X, *b*). Within one or two seasons' growth the primary leaves are followed by the adult form of foliage.

The wood of incense cedar is sometimes rather wide-ringed, but usually it is narrow-ringed and very straight-grained, the heartwood varying in color from a pale or dull yellow-brown to a light brown tinged with red, the sapwood being a creamy white. It is soft, light, a cubic foot of seasoned wood weighing about 25 pounds, and very durable under all kinds of exposure. Its great durability renders it extremely valuable for use in the water or in the ground, where it may remain sound for from 25 to 30 years or more. Large trunks and, to a much less extent, small or medium-sized ones, are often riddled by a "dry-rot fungus," as if by the galleries of a wood-boring insect. This injury, however, is now known to result from the attack of a fungus called *Polyporus amarus*. They necessarily weaken the trunk logs and render much of the wood useless for lumber, but the durability of unattacked portions of the wood is in no way impaired. Trunks not excessively perforated are frequently used for telephone poles, especially in the Pacific slope range of the tree, where, with the exception of redwood and bigtree timber, it is the only lasting wood obtainable for this purpose. In general appearance and texture the wood of incense cedar is quite similar to that of the western red cedar (*Thuja plicata*). It is locally used for several of the same purposes for which the latter is employed, such as fence posts, telephone poles, light-traffic railway ties, shingles and shakes, sash and doors, and "edge-grain" flooring, and some other interior finishing material. Its soft, brittle texture and the ease with which it "chips" has also recently brought this wood into use for cheap grades of lead pencils.

OCCURRENCE AND HABITS.

Libocedrus decurrens occurs more commonly, as a rule, on western than on eastern mountain slopes. It ascends somewhat higher on the western slopes, chiefly because of greater moisture on such exposures. The vertical range of incense cedar in the Pacific slope region varies from about 3,500 to 7,500 feet, in exceptional instances descending as low as 1,500 feet and ascending to about 9,000 feet elevation. In its dry range within the Rocky Mountain region it is confined mainly to canyons, gulches, and cool north slopes, at an altitude of about 7,000 feet (Map No. 7). Incense cedar is adapted to a variety of soils, but grows best in cool, moist, gravelly, porous soils. It occurs also in rather dry soils (warm exposures), yet probably only because it can endure them. With deficient soil moisture, fairly deep, porous soils are essential, while with sufficient moisture the quantity and quality of soil is less important.

In the Pacific slope region incense cedar occurs variously in mixture (but more or less subordinate), scattered singly, or in groups and patches, mainly with western yellow pine, Jeffrey pine, Douglas fir, white fir, red fir, California black oak, and sometimes with bigtree. Under the best conditions for growth in this region it occasionally forms from 25 to 50 per cent of the stand, particularly within the range of western yellow pine and sugar pine. But in its limited range in the Rocky Mountain region incense cedar forms only a very small percentage of the stand and occurs mostly with western yellow pine.

Incense cedar is moderately tolerant, enduring more shade than western yellow pine, western white pine, and Douglas fir, and is usually intermediate or subordinate in mature stands because of its slower growth and greater tolerance. It is adapted both to moderate shade and full light, but requires less light in youth than in later life and tolerates most shade under conditions favorable to good growth. Its tolerance varies, however, not only with age, but also with atmospheric and soil moisture, character of soil, and climate. Rapidity of growth and size attained in later life are checked ordinarily n proportion to the intensity of shade to be endured.

Incense cedar is a prolific seeder every two or three years under favorable conditions of growth, some seed, however, being borne locally about every year. Thrifty, mature trees standing in full sunlight produce the largest amount of seed. Even small scrubby trees in open places usually bear relatively large crops of seed. The seed has a comparatively low rate of germination (15 to 45 per cent) and fairly persistent vitality. Because of their large light wings the seeds are widely distributed by wind. Germination of the seed and growth of seedlings are best in moist vegetable mold, but excellent also on moist mineral soil. Partial shade is favorable to early growth of seedlings because soil moisture is conserved under such conditions. Lack of sufficient soil moisture during the critical early period of growth often results in the death of large numbers of seedlings. Good reproduction occurs under the partial shade of old trees, but it is particularly abundant in open places in thin stands, where dense thickets of young incense cedar frequently exclude other seedling trees. In cool moist places, however, white fir may enter such thickets and later become predominant. Incense cedar is often the first conifer to establish itself at the lower edge of its vertical range in chaparral and oak growth, proving its great adaptation to different degrees of light, moisture, and character of soil, as well as its general hardiness during seedling stages of growth.

LONGEVITY.

Much is yet to be learned regarding the age limits of this tree. So far as is now known, it is long-lived, but the ages of very large trunks have not been determined, chiefly because the centers of old trees are often so completely destroyed by fungi as to prevent counting the earlier growth rings. Narrow-ringed trees from 24 to 36 inches in diameter are from 360 to 546 years old. One wide-ringed tree examined by the author was 42 inches in diameter and only 115 years old, showing exceptionally rapid growth. The largest trees are probably from 600 to 800 years old, or possibly one or two hundred years older.

GENERIC CHARACTERISTICS OF ARBORVITÆS.

The trees belonging to the group which is technically called Thuja are commonly known as "cedars" or arborvitæ.[44] They are medium to very large-sized evergreen trees. The adult form of foliage consists of minute, overlapping, scalelike leaves, arranged as in Libocedrus, and conspicuously flattened on the short side branchlets, which are arranged in one plane, thus forming flat sprays (Pl. XI, XII). The back of the leaf is marked with a tiny gland or small pitlike depression. Seedling leaves are narrowly lance-shaped and sharp-pointed, and spread widely from the stem (Pl. XI, *b*).

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[44] Nurserymen and many writers treating of coniferous trees from the standpoint of horticulture appear to favor calling species of the genus Thuja arborvitæs. A number of botanical writers also favor this. Lumbermen, woodsmen, and others concerned with the use of the wood of these trees, however, uniformly or with few exceptions, designate them as cedars.

The male and female flowers are borne on the same tree, but each sort is usually on different twigs. They are minute, inconspicuous, elongated bodies, especially the female flowers, borne at the ends of the twigs and opening, as a rule, in early spring.

The small solitary cones (Pl. XI) mature in one season, shedding their minute, very narrowly winged seeds in early autumn (Pl. XI, *a*). The cones, strongly bent back upon the branchlets, are composed of about 8 thin scales, which are arranged in pairs, each pair set at right angles with the preceding one, just as in the arrangement of the leaves. The two or three middle pairs of scales, which are larger than the others, each bear two seeds. The thin, gauzy seed wings, attached on two sides of the seed, and always of a lighter color than the body of the seeds, render the seeds very buoyant, so that they are carried by the wind for long distances from the parent trees. Minute resin cells in the seed coats give the seed a strong aromatic or cedarlike odor similar to that of the wood.

The wood of the Thujas is very light, soft, and has a characteristic aromatic or cedarlike odor. It is exceedingly valuable for timber, particularly on account of its durability under all kinds of exposure, and especially in earth and water.

Two species of this group are indigenous to the United States and Canada. One, a small or medium-sized tree, inhabits our northeastern States and adjacent Canadian Provinces; the other, a very large tree, grows in northwestern United States and northward in the Pacific coast region to Alaska.

Trees of this genus are of ancient origin, representatives of them having existed throughout the northern hemisphere during the upper Cretaceous and Eocene periods of the earth's history. Remains of them are found abundantly in the Baltic amber (Oligocene) and in the Miocene of Europe and North America. Geologic remains of our northeastern white cedar, Thuja occidentalis, occur in the Pleistocene formation of Canada, Ohio, and Virginia.[45]

WESTERN RED CEDAR; "RED CEDAR."

Thuja plicata D. Don.

COMMON NAME AND EARLY HISTORY.

Like the incense cedar, the western red cedar occurs chiefly in the Pacific coast region, its range in the Rocky Mountain region being confined to Montana and Idaho and adjacent Canadian territory (Map No. 8).

Lumbermen and other woodsmen of the Northwest call it "red cedar," or simply "cedar," while for the most part nurserymen know it as "giant arborvitæ."[46] Northwestern woodsmen also call it "canoe cedar," because the Indians use the easily worked big trunks for canoes. The name "red cedar" is fairly applicable to the dull, slightly reddish brown wood, but use of the name for Thuja plicata would at once confuse this species with the eastern red cedar (*Juniperus virginiana*), which has really red wood, and was discovered nearly a century before the western cedar became known to science. It seems best, however, to adopt the common name western red cedar for Thuja plicata in order to avoid confusion that would result from applying the name "red cedar" to two different trees.

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[45] Fide Dr. Edward W. Barry, paleontologist, Johns Hopkins University, Baltimore, Md.

Western red cedar was first discovered by Luis Née on Nootka Sound some time during the years 1789 to 1794,[47] in which Née served as one of the botanists who accompanied the Spanish explorer Malaspina in his voyage around the world. Two years later (1796), Archibald Manzies found it on Vancouver Island while he was serving as surgeon to Capt. Vancouver on the latter's voyage to the Northwest coast. It was probably later introduced from this region into European gardens, where it appears to have been cultivated long before it became known to botanists.

The first technical name applied to the western red cedar is "Thuya plicata" of D. Don, who properly published it in 1811, although in 1807 James Donn published the bare name Thuya plicata (without a description), and attached it to Née's original specimen of this cedar. Thuja[48] plicata is, therefore, the technical name by which western red cedar should now be known. Western red cedar was, however, long and exclusively known to botanists as "Thuya gigantea Nuttall," a name which was established in 1834, 23 years after "Thuya plicata" was published. The latter name was not restored to use at an earlier date chiefly because the plants cultivated as "Thuya plicata" in European gardens were believed to represent more nearly forms of our northeastern white cedar (*T. occidentalis*) than of the western red cedar.

Just when Thuja plicata was first discovered in the Rocky Mountain region is unknown. Probably, however, it was in about 1832 or 1833, and doubtless Nathaniel Jarvis Wyeth was the first American collector to secure botanical specimens of the tree in that region. Thomas Nuttall,[49] who described Wyeth's specimens, informs us that Wyeth's collection of plants, including western red cedar, was obtained "chiefly in the valleys of the Rocky Mountains or Northern

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[46] A common name coined from the technical name Thuja gigantea, formerly applied to this species but now replaced by T. plicata, the oldest name for the tree.

[47] M. T. Masters, in Gard. Chron. XXI, 3d Series, 101, 214, 1897, the specimen collected by Née being preserved in the Natural History Museum at South Kensington, England.

[48] Linnæus' later spelling, Thuja (Hort. Cliff. and Spec. Plantarum, 1737, 1753), is here maintained in place of the first spelling, Thuya.

[49] Journal of the Academy of Natural Sciences, VII, part 1, 5, 1834.

Andes, toward the sources of the Columbia River." A little further on in his paper (l. c.) Nuttall says "This collection was made wholly on the returning route of Mr. Wyeth from the falls of the Columbia to the first navigable waters of the Missouri."[50]

About a dozen named horticultural varieties of western red cedar have originated in European gardens, and all are distinguished by the color of the foliage, habit of the branches, and form of the crown. Five of these are fairly distinct as garden forms in the shape of the crown, habit of the branches, and coloration of the foliage. Thuja plicata gracillima (Beissner) Sudw. is distinguished by its small delicate branches. When grown in rich, moist soil this form produces the stouter branches, showing a tendency to revert to the normal type. T. plicata compacta (Carr.) Beissner has a compact fastigiate crown of thin delicate branches. T. plicata penduliformis Sudw. has long, slender, drooping branches and twigs, similar in general appearance to the weeping willow. T. plicata atrovirens (Gord.) Sudw. is distinguished by exceptionally dark-green brilliant foliage. T. plicata variegata Carr. has golden-yellow mottled foliage, while a similar form, T. plicata albo-maculata (Hort. ex Beissner), has white-mottled foliage.

DISTINGUISHING CHARACTERISTICS.

Perhaps the most prominent characteristic of western red cedar is its decidedly conical trunk form, which, in the case of very old trees, includes an enormously developed base ("swell-butted"), the latter being conspicuously infolded or fluted for from 10 to 20 feet above the ground. The thicker layers of wood formed on these ridges appear to be made at the expense of the thinner layers of wood in the intervening hollows, the different rates of growth thus resulting in a fluted trunk. The fluted appearance is less pronounced in the case of small trees. Height and diameter growth varies greatly from the largest development, which is attained chiefly in the Pacific region, to medium or small-sized trees produced in the Rocky Mountain region; while at high elevations in both regions trees are often only a few feet high. Large trees are from 150 to 175 feet in height, or very exceptionally from 190 to 200 feet, with diameters of from 5 to 8 feet, or, in the case of very old trees, sometimes from 10 to 18 feet through.[51] Small and medium-sized trees range from 60 to 120 feet in height and from 2 to 4 feet in diameter. The enormous girth of the largest trees is at the base; their diameter decreases so rapidly that at 20 feet from the ground they may be no more than 9 or 10 feet in diameter. In such trees, from 60 to 100 feet of clear trunk is common, while the clear trunk of smaller trees is from 10 to 50 feet. It is only in densely crowded stands that trees have long, clear trunks, and even then they often have scattered branches below the main crown. The boles of young trees are fairly straight, but large trees are frequently bowed or slightly bent and are rarely perfectly cylindrical.

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[50] According to Elwes and Henry (l. c.), W. Lobb introduced Thuja plicata into cultivation in England in 1853, the trees raised in Veitch's nursery at Exeter having been distributed under the name "Thuja lobbi." These authors state that the largest trees now growing in England were raised from seed planted in about 1860, and were, in 1906, approximately 95 feet in height and 3¼ feet in diameter. Many trees in various parts of Great Britain now over 60 or 70 feet high were grown from seed within 50 years. The above authors state that Thuja plicata flourishes also in Wales, Scotland, and Ireland, where there are a number of trees from 60 to 70 feet high and from 2 to nearly 3 feet in diameter. The excellent timber and ornamental form of this tree and its rapid growth have made it a favorite in Great Britain, where small forest plantations of it already have been set out.

As nearly as can be ascertained, Thuja plicata was first grown in Germany in about 1878. Few of the trees raised, however, survived serious injury from late frosts and the fungous disease known as Pestalozzia funerea, this disease killing many of the trees after they had reached an age of 10 years. In the early nineties the German Government imported considerable quantities of the seed of this species to test further the tree's value for forest planting in Germany. The tree was also extensively tested in Austria. Little is known now of the exact results of all of these trials, except that late frosts and the above-mentioned fungous disease greatly hindered the growth of the trees.

Thuja plicata has been sparingly planted for ornament in our northern and middle Atlantic States. Prof. C. S. Sargent (Silva, X, 130, 1896) says it endures the winters of eastern Massachusetts. Seedlings raised from seed sown in the spring of 1916 at Letchworth Park Forest and Arboretum, Wyoming County, N. Y., have survived the winter of that year and probably will prove hardy in that locality, although at least several years' trial are necessary to establish this as a fact.

Young trees have narrow, open, conical crowns reaching almost to the ground and tapering to a sharp top, the slender whiplike leader usually nodding in a graceful curve. Old trees in dense stands have only a short, blunt, or round-topped conical head. A notable characteristic of western red cedar is the frequent production of two leaders, which combine in forming a dense crown. Except when growing in very dense stands, trees retain practically all their branches until they are 18 or 20 inches in diameter and from 50 to 80 feet high, while trees growing in the open become much larger before they lose their lower branches. On young trees the slender branches all curve upward, but later as the limbs become very long, the lower ones droop and those higher swing down in a long, graceful curve, with an upward sweep at the ends. The flat, lacelike, yellow-green side sprays hang from the branches like lines of fringe.

The bark of western red cedar is thin, even that of old trunks being only from five-eights to seven-eights of an inch thick. Because of its thin bark this tree rarely escapes being fatally injured by fire. Freshly broken bark is of a clear, reddish, cinnamon-brown color, but externally it is often weathered to various shades of grayish brown, depending upon exposure to the light. The bark is distinctly but shallowly seamed, the narrow ridges being flat on young trees and rounded on old trunks. The main ridges run irregularly but continuously, with rare breaks, and are connected at short inter-

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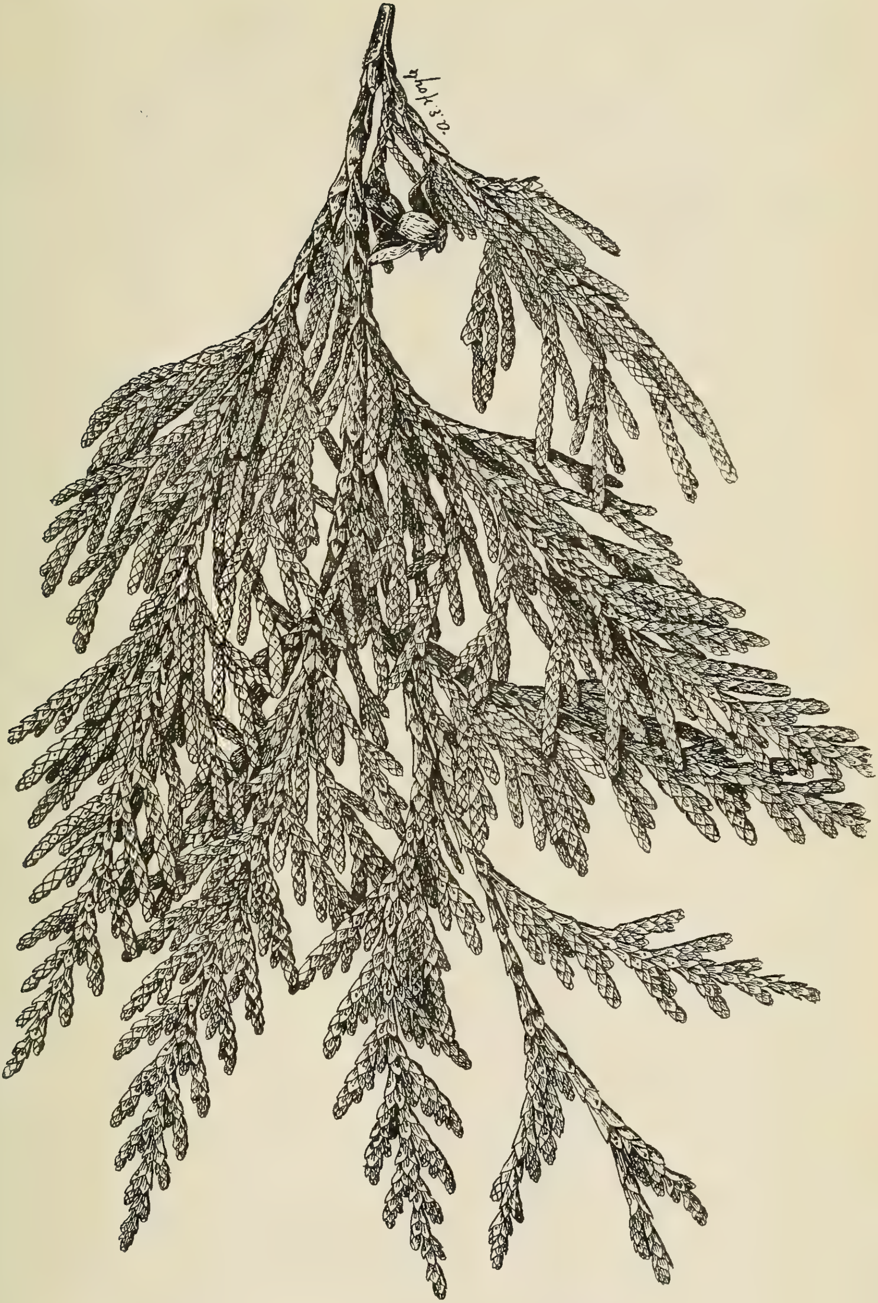
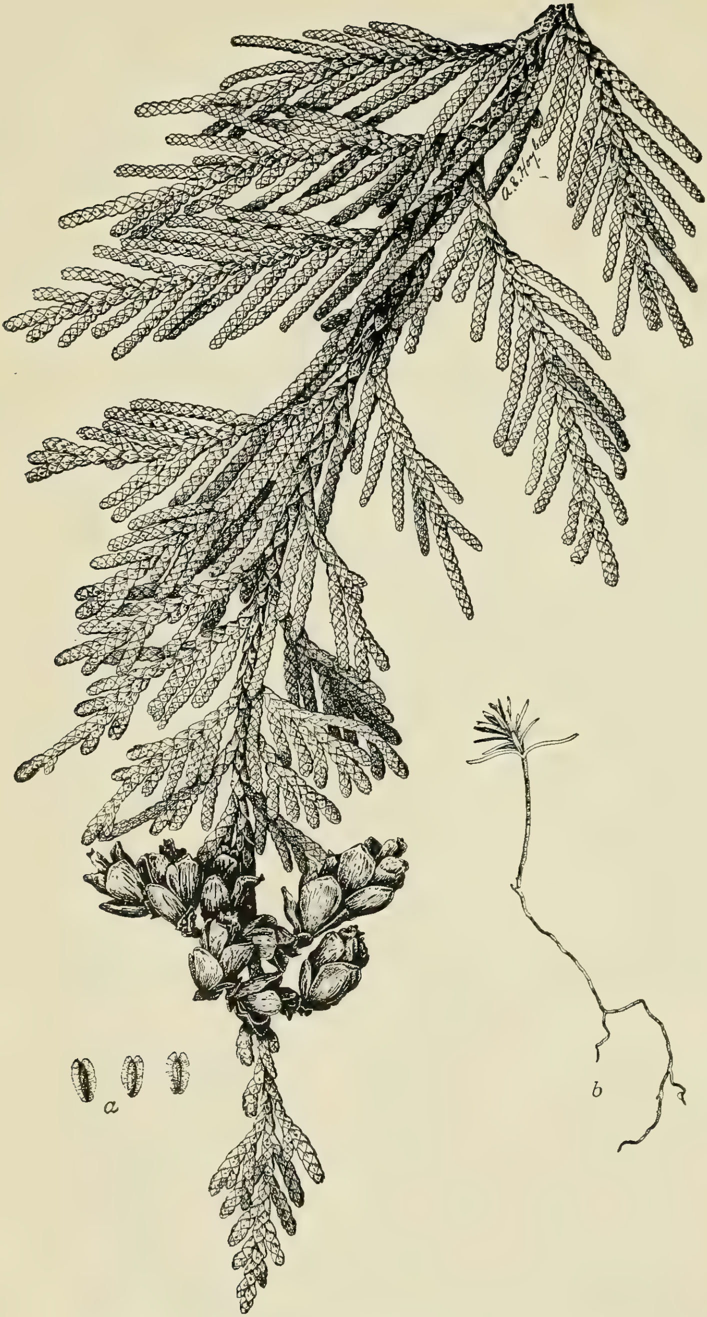
[51] Under date of February 12, 1909, a letter from Mr. F. H. Conant, of Auburn, Wash., gives the diameter of a western red cedar cut in sec. 8, T. 23 N., R. 9 E., west slope of the Cascade Mountains, King County, Wash., as 18 feet 4 inches at a point 12 feet above the ground. The height of this tree could not be accurately measured because the top was dead and had been broken off. Mr. Conant mentions another tree about the same size standing near the tree cut. A decay at the center of the tree cut was 6 feet in diameter. Allowing sufficient time for the tree to have attained 6 feet in diameter, the writer found that by counting the annual layers of growth in the sound wood this cedar must have been approximately 2,265 years old when it was cut.



Thuja plicata: Foliage and Open Cone.



THUJA PLICATA: FOLIAGE AND CLUSTER OF OPEN CONES.

a, Seeds and their wings; *b*, seedling 2 months old.

als by thinner diagonal ridges and fibers. In texture and appearnce the bark is more or less stringy and fibrous, so that in the case f young trees it may be separable into long, thin strips, while in he case of old trees the bark is separable only into shorter scales. he inner bark is very tough and strong, particularly that of young rees, from which Indians peel strips of bark 20 or 30 feet long for asket making.

The small scalelike leaves (Pls. XI, XII), the arrangement of which s described under the "Generic Characteristics of Arborvitæs," emain on the trees about 3 years. Leaves of vigorous leading hoots usually have a tiny gland on the back side, while the leaves of he more slowly grown lateral twigs are marked on the back by a mall pitlike depression. As the main stems of a branch grow, heir short, flat, side branchlets die and fall during their second ear, as is the case also with similar sprays of Libocedrus. The eathery-brown cones (Pl. XI), which mature by the end of August, ave about 6 seed-bearing scales, each of these producing from 2 to seeds. After shedding their light double-winged seeds (Pl. XI, *a*) the cones remain on the trees until the following spring or summer. The seed-leaves, 2 in number, are opposite, lance-shaped, and about one-fourth of an inch long (Pl. XI, *b*—lowermost pair). The primary eaves, those that succeed the seed-leaves, are similar to the latter in form, and like them also they are widely spread and more or less bent downward. The still shorter, spreading, sharp-pointed, scalelike leaves produced next are somewhat similar in form to those on adult trees, and appear at the end of the first or second year's growth. Leaves produced a year or two later are like those of adult trees.

The wood of western red cedar is very soft and brittle, and has a strongly aromatic odor. It is the lightest in weight of all the coniferous woods in the Rocky Mountain region, a cubic foot of seasoned wood weighing only about 23½ pounds. When freshly cut, the thin layer of sapwood is whitish and the heartwood is a dull, slightly reddish brown, this tinge being lost by gradual exposure to the light, and replaced by a yellowish brown. The annual layers of growth vary in thickness from moderately wide to narrow. The straight grain of this wood renders it easy to split and its soft texture makes it one of the easiest to work. Great durability under all sorts of exposure is one of its most important commercial qualities. Large logs have lain half buried in wet ground for over 50 years with but little decay of the heartwood. On account of its durability and the large clear cuts obtainable, western red cedar is very extensively used for shingles, as well as for other commercial purposes requiring large dimension pieces. It is also much used in combination with Douglas fir in the manufacture of doors. Young timber supplies large quantities of telegraph and telephone poles, as well as light-traffic railway ties and posts.

OCCURRENCE AND HABITS.

Western red cedar is confined almost entirely to regions of abundant precipitation and atmospheric humidity, and chiefly also to wet or constantly moist situations (Map No. 8). Occasionally, however, it occurs on moderately dry slopes and warm exposures, but here it is always stunted. In the Rocky Mountain region western red cedar occurs mainly at elevations between about 2,000 and 7,000 feet, the largest and best-formed trees occurring below 5,000 feet, mostly small trees or shrublike forms being found above this level. Only shrubby growths occur in the highest places. The tree generally grows on moist flats, river bottoms, benches, gentle slopes, in and about swamps and wet, springy places, and in cool, moist gulches and ravines. Abundant soil moisture is on the whole more important than quantity or quality of soil; both are, however, essential for the best growth. Western red cedar forms dense pure stands of only limited extent, the formation of small pure patches and groups being especially characteristic. These growths are usually interspersed or otherwise mingled with western hemlock, Douglas fir, lowland white fir, western white pine, western larch, lodgepole pine, Engelmann spruce, and western yew. Its most frequent associates are lowland white fir and Engelmann spruce.

Western red cedar is in general very tolerant of shade. This quality varies, however, with age, altitude, latitude, amounts of soil and atmospheric moisture, and climatic conditions. The tree grows well in dense shade during seedling and early pole stages of life, and may even reach maturity and old age under constant shade; but rapidity and fullness of growth are retarded in proportion to the density of shade; for although a high degree of shade is tolerated without retarding growth during early life, it is not required in middle and later life. Tolerance is greatest under the best conditions for growth and toward the lower limits of the tree's vertical range. Here it maintains a dense crown cover throughout life and commonly forms an understory, alone or with lowland white fir, western white pine, and other species. The density of pure (limited) stands of seedlings and later young growths is so great as to exclude all intolerant, and often some tolerant, associates. Compared in tolerance with other conifers of its range, western red cedar ranks with Tsuga mertensiana, Chamæcyparis nootkatensis, Picea engelmanni, and Taxus brevifolia.

Thuja plicata is a prolific seeder, specially heavy seed production occurring at intervals of two or three years. The seed has a rather high rate of germination but only transient vitality. It falls from he ripe open cones quickly and is easily disseminated by wind, ısually germinating the autumn it is shed, and the seedlings establ ishing themselves before winter. Germination is abundant and best n moist duff, litter, moss, decayed logs, stumps, etc., both in the pen and in the densest shade, where seedlings hold their ground with emarkable power. The tree does not reproduce itself readily vhere frequent fires have destroyed the ground cover or forest over to such an extent that soil moisture is materially reduced. onsiderable quantities of the seed are eaten by squirrels.

LONGEVITY.

Western red cedar is a slow-growing tree and the extreme age ttained is at present imperfectly known, chiefly because the centers f the largest trees cut are usually decayed, thus preventing an ccurate count of the annual rings of growth. It may, however, e regarded as very long-lived. Trees 24 to 40 inches in diameter re from 200 to 510 years old. Some of the largest trees are unuestionably from 800 to 1,000 years old.[52]

FAMILY RELATIONSHIPS OF YEW TREES.[53]

The trees and shrubs which belong to the family Taxaceæ (yews r yewlike trees) differ fundamentally from the true cone bearers, oniferæ, in producing male flowers on one tree and female flowers n another, flowers of both kinds very rarely occurring on different arts of the same tree. The conifers usually bear male and female owers on the same tree, each sort being on different branches or arts of them.[54]

The leaves of Taxaceous plants are evergreen, flat, narrowly ance-shaped, and appear to grow (in our native species) in spreading nes on two opposite sides of the branches (Pl. XIII). The fruits iffer from those of conifers in being almost or entirely enveloped n a pulpy covering. In the case of the yews of this group it is a mall, berrylike, bright-colored cup (Pl. XIII, *a*), the hard seed eing embedded in a juicy, sticky outer pulp.

In the case of other members of the family the covering of the fruit s firm, practically complete, and similar in appearance to an olive.[55]

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[52] See footnote No. 51, p. 36.

[53] The class relationship of the yew trees is briefly discussed in Forest Service Bulletin No. 207, The ypress and Juniper Trees of the Rocky Mountain Region, p. 3, 1915.

[54] There are, therefore, fewer seed-bearing individuals among the yews and their allies than among ne-bearers, since only trees bearing female flowers produce seed. Hence, in thinning a stand of Taxaous timber both male and female trees should be preserved as near to each other as possible if reseeding expected to take place, for pollen of the male flowers is carried to the female flowers only by the wind. male trees are distant more than 25 or 30 yards from the female tree, only the strongest wind, blowing the right time, will effect fertilization.

[55] See fig. 75, Forest Trees of the Pacific Slope, p. 192, 1908.

GENERIC CHARACTERISTICS OF YEW TREES.

The yews belong to a generic group technically known as Taxus. They comprise both trees and shrubs, and while as a group they are very distinct from other Gymnosperms, they are not strikingly distinct as species. For example, there is great similarity in the appearance, structure, and qualities of the wood of different species, and also in the general appearance and form of their foliage and fruit. The characteristics mainly relied upon to distinguish the different species are the shape of the plant, habit of growth, and some minor differences in the form and color of the leaves. The arborescent representatives of this group are world-renowned trees. The wood of one species of yew tree inhabiting Europe, Asia, and Africa was long used by ancient tribes for bows, which were the most important implements of war. In modern archery the wood of this yew tree still holds the highest rank among bow woods.

The yews are evergreen plants, their leaves remaining on the twigs for many years. In form the leaves are flat, narrowly lance-shaped, and sharp-pointed. They are arranged somewhat spirally on the branches, but by a twist at their bases they usually appear to grow in two lines, on opposite sides of the twigs[56] (Pl. XIII).

The male and female flowers of the yews are borne on different trees (exceptionally, flowers of both sexes sometimes occur on different branches of the same tree). Male or pollen-bearing flowers are small, yellowish, budlike bodies produced singly and rather abundantly on the under sides of the branches, while the much less numerous female flowers, small greenish bodies, occur similarly on the branches. The latter develop into fruits (Pl. XIII, *a*), which ripen in one season and usually fall to the ground shortly after maturity. The ripe fruit[57] is a thin-skinned berrylike body, with a bright coral-red, sweetish, mucilaginous pulp, in which a single hard seed appears to be embedded nearly to its point. The seed-leaves are regularly two in number.

The purple or brown bark of yews is very thin. The exceedingly narrow-ringed, dense wood varies in color from a clear rose-red to

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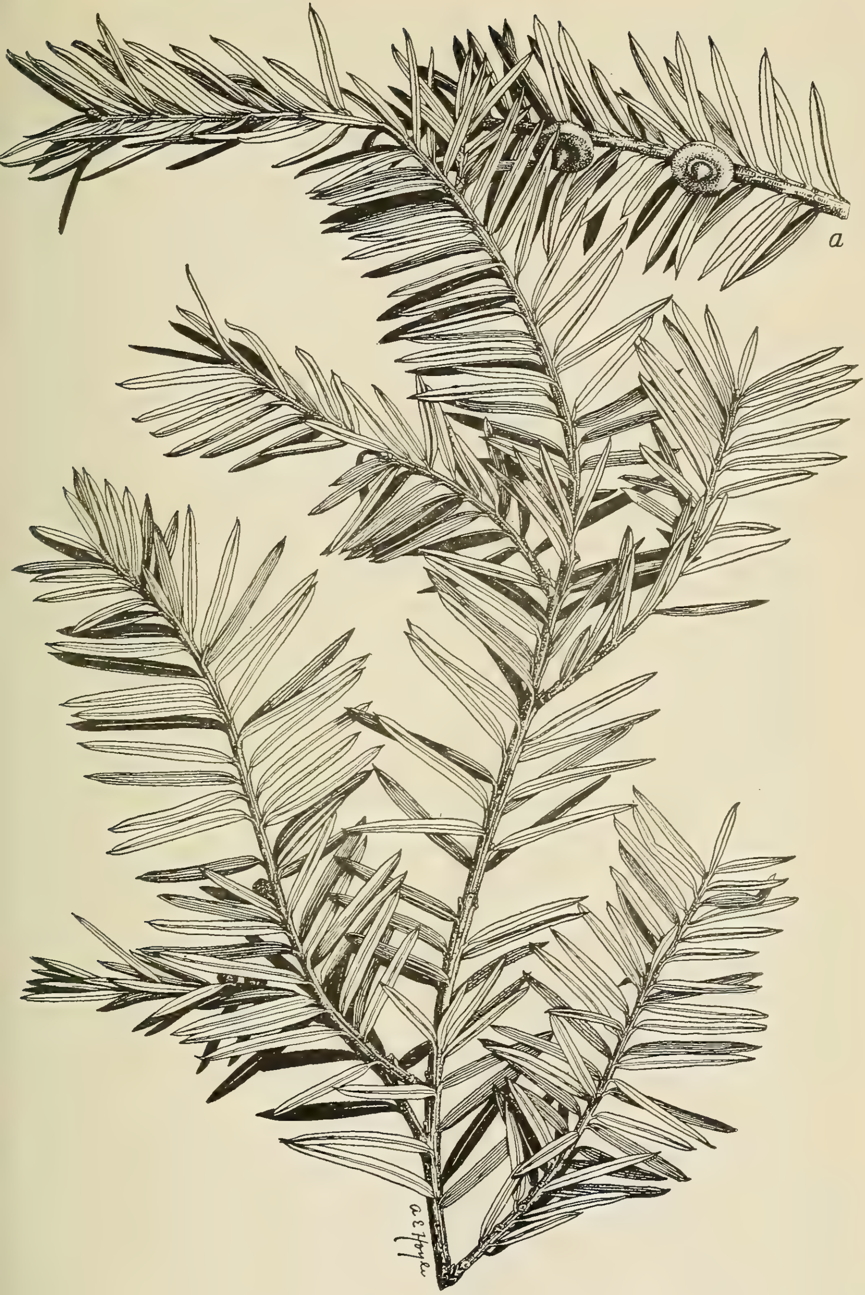
[56] The main vigorous shoots of the compact columnar forms of the European yew tree produce leaves with a spiral arrangement, but the ordinary form of this tree bears leaves apparently in two lines.

[57] The seed and leaves of the common European yew tree (*Taxus baccata* Linn.) are known to be deadly poison to human beings and animals when eaten. It is believed that the poison resides in the seed and also in the leaves, from both of which W. Marme obtained by chemical analysis a white, crystalline, poisonous powder named "taxine." Symptoms of poisoning from this plant are semiunconsciousness, cold clammy skin, convulsions, difficult breathing, dilated pupils, and attempted vomiting. (U.S. Dispensatory, sixteenth and nineteenth editions.) While nothing appears to be known concerning the effect of eating the fruit and foliage of our native yews, the very close relationship of these to the European yew tree would indicate that the seed and foliage of our yew trees are similarly poisonous and should, therefore, be avoided. The sweetish pulp of yew fruits is not poisonous, for the mountaineers of northwestern India are said to eat this part of the fruit of Taxus baccata, while cattle of the region are said to eat the foliage and twigs of this plant without injury. It is probable, however, that most browsing animals rarely eat enough of the foliage to get the deadly effect. (Fide Brandis, For. Fl. Brit. Ind. 541.)



TAXUS BREVIFOLIA: FOLIAGE.

a, Twig bearing fruit (attached to under side of branchlet).

dark reddish brown. It is extremely durable under all kinds of exposure and has remarkable elasticity.

The yew trees are of small or medium size, but they live to a great age, specimens of the common European yew tree being said to have attained an age of from 2,000 to 3,000 years. A marked characteristic of the yews is their ability to reproduce themselves by permanent sprouts from cut stumps, and to grow also from cuttings.

Seven different species of yew are now known,[58] two of these occurring in Europe, Africa, Asia, and Japan, and four species in North America. Three of the North American yews inhabit the United States and adjacent portions of Canada, while so far as is now known, a fourth is confined to Mexico. One of our species, a small tree, is confined to Florida; another is a shrub growing in our northeastern States and in adjacent Canadian Provinces; while the fourth species, a small or medium size tree, inhabits our Pacific and northern Rocky Mountain forests, extending northward into adjacent Canadian territory (Map No. 9).

The yews are of very ancient origin. Fruits of Taxus have been found in the European Oligocene, while remains of the European yew tree (*Taxus baccata* L.) have been discovered in the late Miocene of Europe and are also common throughout the Pliocene and Pleistocene of that region. Remains of a shrubby species now living and known as Taxus canadensis Marsh. have been found in the Pleistocene of Manitoba, Ontario, Nova Scotia, Iowa, and Illinois.[59]

WESTERN YEW.

Taxus brevifolia Nuttall.

COMMON NAME AND EARLY HISTORY.

Taxus brevifolia is little known as a distinct species except to botanists and foresters. Woodsmen within its natural range are familiar with it, but they call it simply "yew." The common name western yew, suggested here, is desirable because it serves to avoid confusion of this tree with the two other yews that occur in the United States.

The earliest record we have of the discovery of western yew is by the Scotch explorer David Douglas, who found it in 1825 on the lower Columbia River, Oreg. William Jackson Hooker, an English botanist, published the first account of it in 1839, but he treated it as a form only of the European yew, Taxus baccata Linneus, which became known to botanists in 1753. It remained for Thomas Nuttall to distinguish and to give this northwestern tree its present technical name, Taxus brevifolia, which was published in 1849.[60]

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[58] Elwes and Henry (The Trees of Great Britain and Ireland, I, 100, 101, 1906) have reduced six of these to varietal rank under Taxus baccata.

[59] Fide Dr. Edward W. Berry, paleontologist Johns Hopkins University, Baltimore, Md.

DISTINGUISHING CHARACTERISTICS.

The western yew is a small tree from 20 to 30 feet in height and from 6 to 12 inches in diameter, occasionally attaining a height of from 40 to 75 feet and a diameter of from 18 to 30 inches. The largest trees occur in the Pacific slope region. As found in the Rocky Mountain region, western yew rarely equals 25 feet in height, and frequently it is only a shrub. The trunks are straight and conical, but conspicuously ridged and fluted as if by an infolding of the surface. Diameter growth is often very eccentric (larger on one side of the pith than on the other). Except in the case of large old trees, the crown has an open conical form and extends nearly or quite to the ground, the slender branches standing out straight and often drooping somewhat, while from their sides and extremities very slender branchlets hang down, giving the tree a weeping appearance. This latter habit is strongly marked in trees growing partly or wholly in the open, because here the densely leafy branchlets are very much more numerous than on trees growing in deep shade. The crowns of old trees are usually rounded and often unsymmetrical.

The purplish bark is conspicuously thin, rarely over one-fourth of an inch thick, and composed of thin, paperlike, easily detached scales, beneath which the newer unexposed bark is a clear rose-red or purple-red.

The deep yellow-green leaves (Pl. XIII), from one-half to three fourths of an inch long, are soft to the touch, and much paler on their under sides than on the upper; their yellowish slender stems are about one-sixteenth of an inch long. Leaves produced each year remain on the trees in a green and functional condition for about five years; occasionally, a few green leaves from 6 to 9 years old are found here and there on branches.

The bright coral-red fruit (Pl. XIII, *a*) is ripe in September and begins to fall during October. Birds often eat the fruit for its sweetish mucillaginous covering, but the hard-shelled seeds are unaffected by digestion. The attractiveness of the fruit to birds serves, therefore, as an important means of disseminating the seed, which otherwise would not be carried far from the parent trees. The short, flat, pointed seed-leaves are two in number. Nothing can be said now regarding the subsequent early growth and characteristics of seedlings, which have not been fully studied.

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[60] According to Veitch (Man. of Coniferæ, ed. 1, p. 305, 1881) Taxus brevifolia was first introduced into cultivation in European gardens in 1854 by Veitch & Sons through their collector, William Lobb. But in the "New and Greatly Enlarged Edition" of Veitch's Manual of Coniferæ (p. 143, 1900) the statement is made that Taxus brevifolia was introduced into British gardens in 1854 by William Murray. To what extent this yew has been planted in European gardens and how well it has succeeded there appears to be imperfectly known. Veitch (l. c.) says the tree is still exceedingly rare in British gardens. Elwes and Henry (The Trees of Great Britain and Ireland, I, 108, 1906) state that they know of no specimens of large size in England.

Taxus brevifolia produces extremely narrow-ringed, clear, rose-red heartwood, which, with exposure to the light, gradually becomes a duller red, the thin layer of sapwood being a very pale yellow when freshly cut. The wood is dense, rather heavy, and when thoroughly dry a cubic foot of it weighs nearly 40 pounds. Thoroughly seasoned wood of this yew is remarkably durable, even in an unprotected state, when used in contact with earth or in water. Owing to the scarcity of the trees, however, the wood is of little commercial importance. Great durability and elasticity render it useful mainly for such articles as canoe paddles and bows; and its attractive color makes it suitable, also, for small cabinet work. As a forest tree, it is only of very secondary importance, both because of its rarity and the fact that larger and more generally useful timber trees grow abundantly in the same range. On account of its remarkable tolerance of dense shade it can, however, assist in forming low protective cover in moist coves and canyons and at the heads of mountain streams.

OCCURRENCE AND HABITS.

Taxus brevifolia grows near the margins of low mountain streams, on moist flats and benches, in deep ravines and coves in rich rocky or gravelly soils, or sometimes in rather dry soils of slopes and ridges. Its altitudinal range is from about 2,000 to 8,000 feet. Tree forms of it occur chiefly below 5,000 feet, while shrubby forms are found mostly above this elevation (Map No. 9).

Western yew occurs only in small groups or scattered singly, mainly as an undergrowth, with western white pine, lowland white fir, western larch, Engelmann spruce, lodgepole pine, and western red cedar. It is a frequent, and often the only, undergrowth with the western red cedar. In its Pacific slope range western yew is often associated also with Chamæcyparis nootkatensis and occasionally at high elevations with Pinus albicaulis.

Like all of the other representatives of this group, the western yew is exceedingly tolerant of shade throughout its life. However, when growing under dense shade, it maintains a comparatively open crown with rather thin foliage, partial shade or full light producing a much more densely branched crown and fuller foliage. The contrast between trees grown in dense shade and those grown in full enjoyment of sunlight is very striking.

Western yew is a fairly prolific seeder, but at rather irregular intervals. The vitality of the seeds is persistent, and the percentage of germination is moderately high, being from 50 to 60 per cent.

Seedlings occur, however, only occasionally, and most frequently in deep shade on wet moss and decaying wood. The generally scattered occurrence of this species and the fact also that only female trees bear fruit, which is much eaten by birds, doubtless account for the sparse, often rare, occurrence of seedling growth.

LONGEVITY.

The extreme age attained by the western yew has not been determined. Its growth in height and diameter is very slow, particularly under deep shade; but even here the tree maintains itself most persistently, indicating that it is long-lived. Comparatively few sound trees of even moderately large size appear to have been studied. Trees 6 inches in diameter are from 75 to 90 years old, while trees from 12 to 20 inches in diameter are from 140 to 245 years old. The largest specimens are believed to be at least 350 to 375 years old. Owing to the fact that the largest trees are so often punky at the center it will be difficult to determine satisfactorily the extreme age of this yew.

KEY TO GENERA AND SPECIES.

Leaves needle-shaped and borne singly:
Bark of the trunk very thin, smooth or loosely scaly and purple. . *Taxus brevifolia*
Bark of the trunk rough; thick and furrowed, or thinnish and with firm scales—
Leaves with distinctly formed delicate stems—
Cones ¾ to 1¼ inches long; flat leaves in 2 thin lines. . . . . *Tsuga heterophylla*
Cones 1½ to 3 inches long; rounded leaves not in lines. . . . . . *Tsuga mertensiana*
Leaves contracted at the base but without distinctly formed stems—
Cones bearing conspicuous, 3-pointed bracts. . . . . *Pseudotsuga taxifolia*
Leaves in brushlike clusters of from 12 to 40—
Cones about one-half an inch long and without exserted bracts. . *Larix laricina*
Cones 1 to 2 inches long and with exserted bracts—
Trunk bark thick, from 3 to 6 inches thick and deeply furrowed, *Larix occidentalis*
Trunk bark thin, from one-half to three-fourths of an inch thick and slightly furrowed. . . . . *Larix lyallii*
Leaves scalelike, borne in pairs and closely overlapping each other:
Cones borne near the ends of twigs; seeds winged on two sides. . . . . *Thuja plicata*
Cones borne at the ends of twigs; seeds winged at one end. . . . . . *Libocedrus decurrens*

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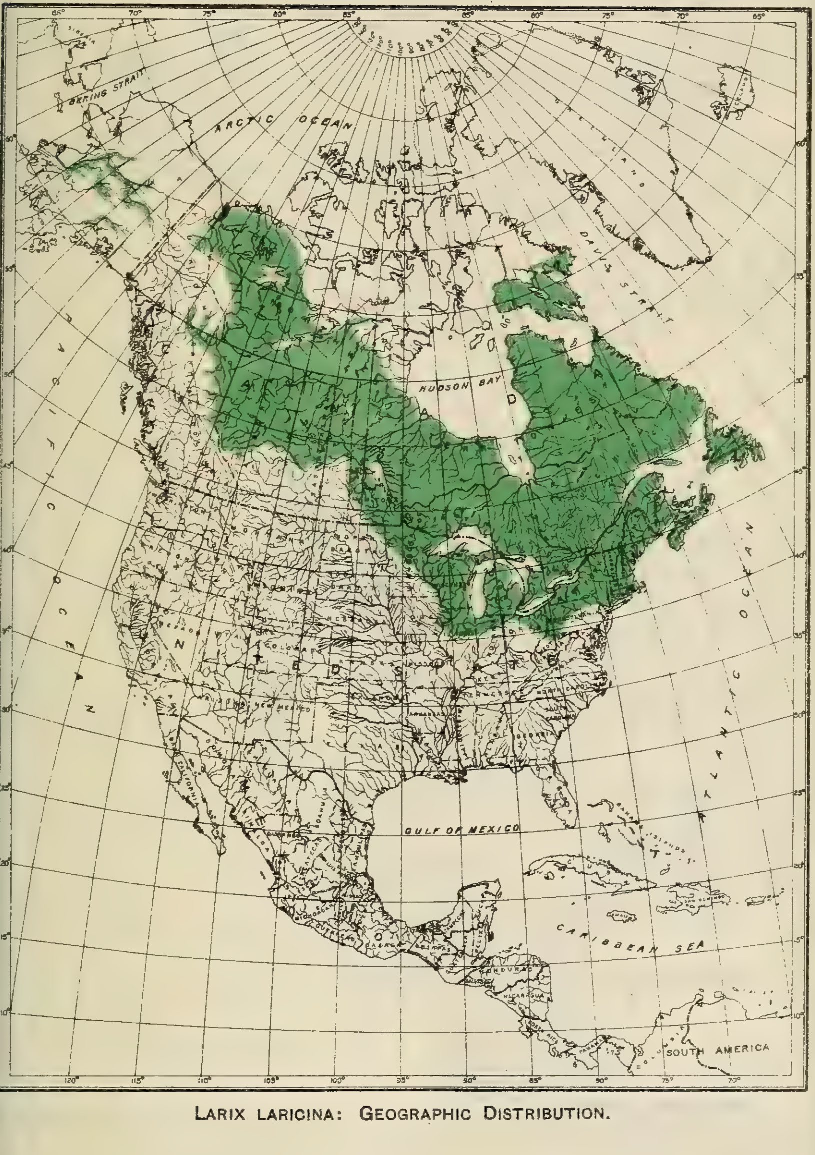

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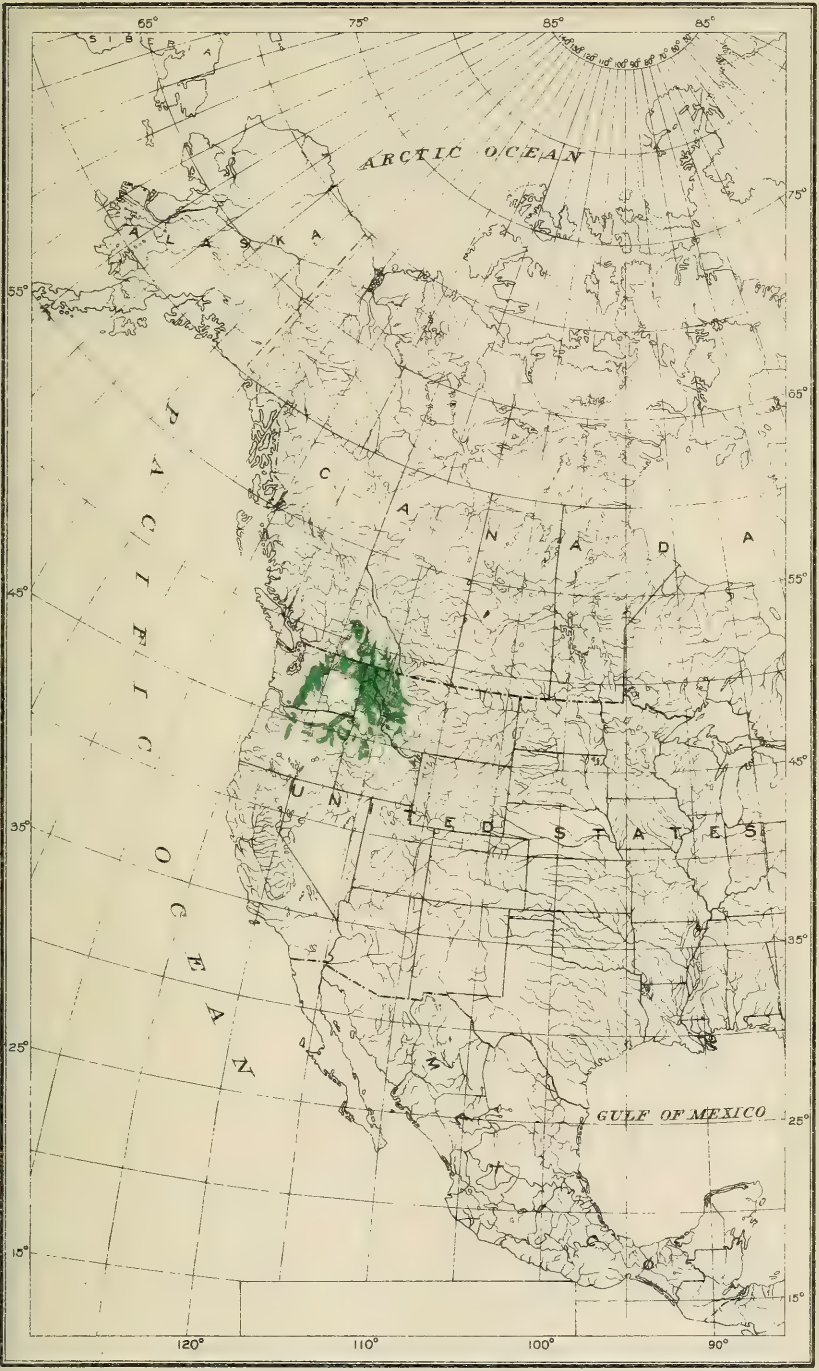

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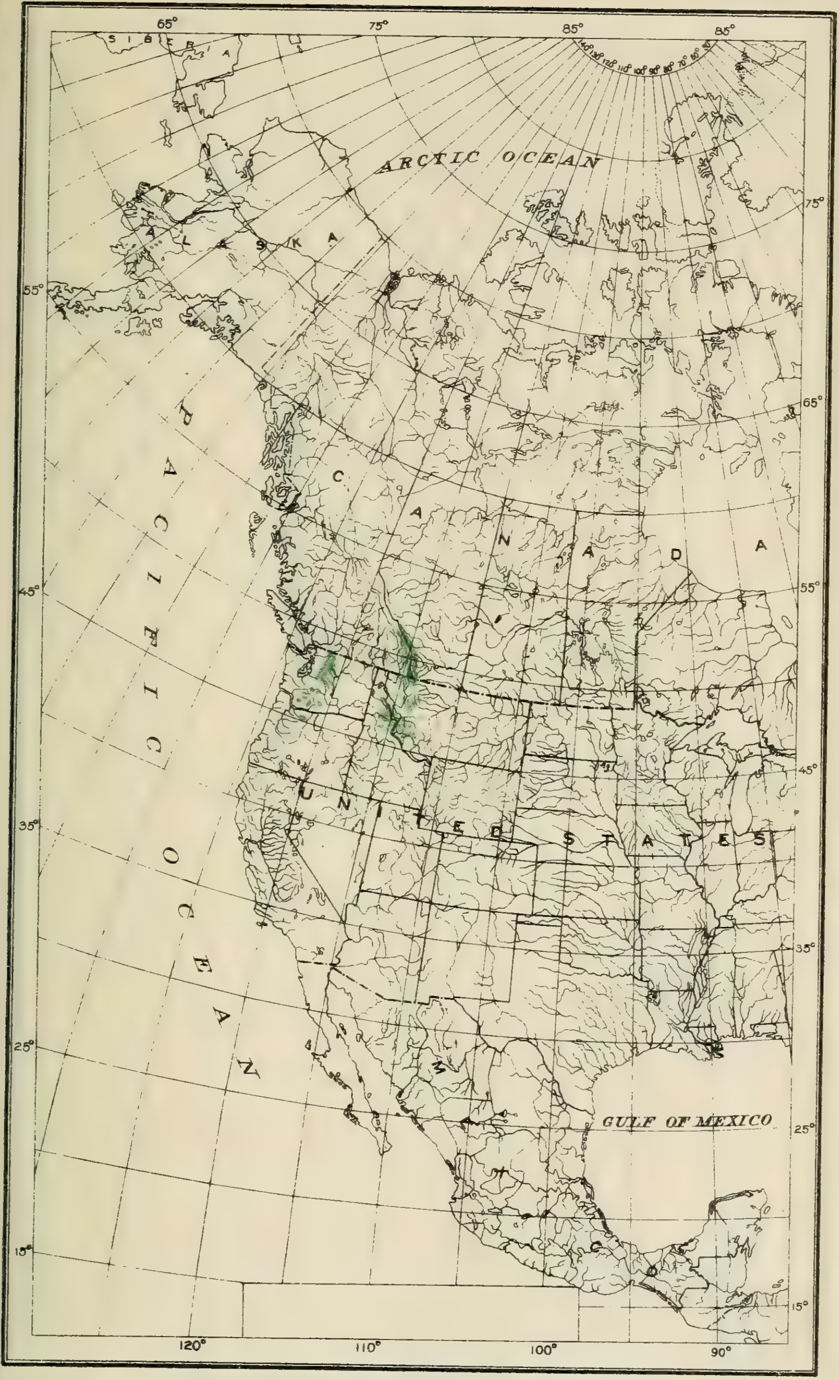

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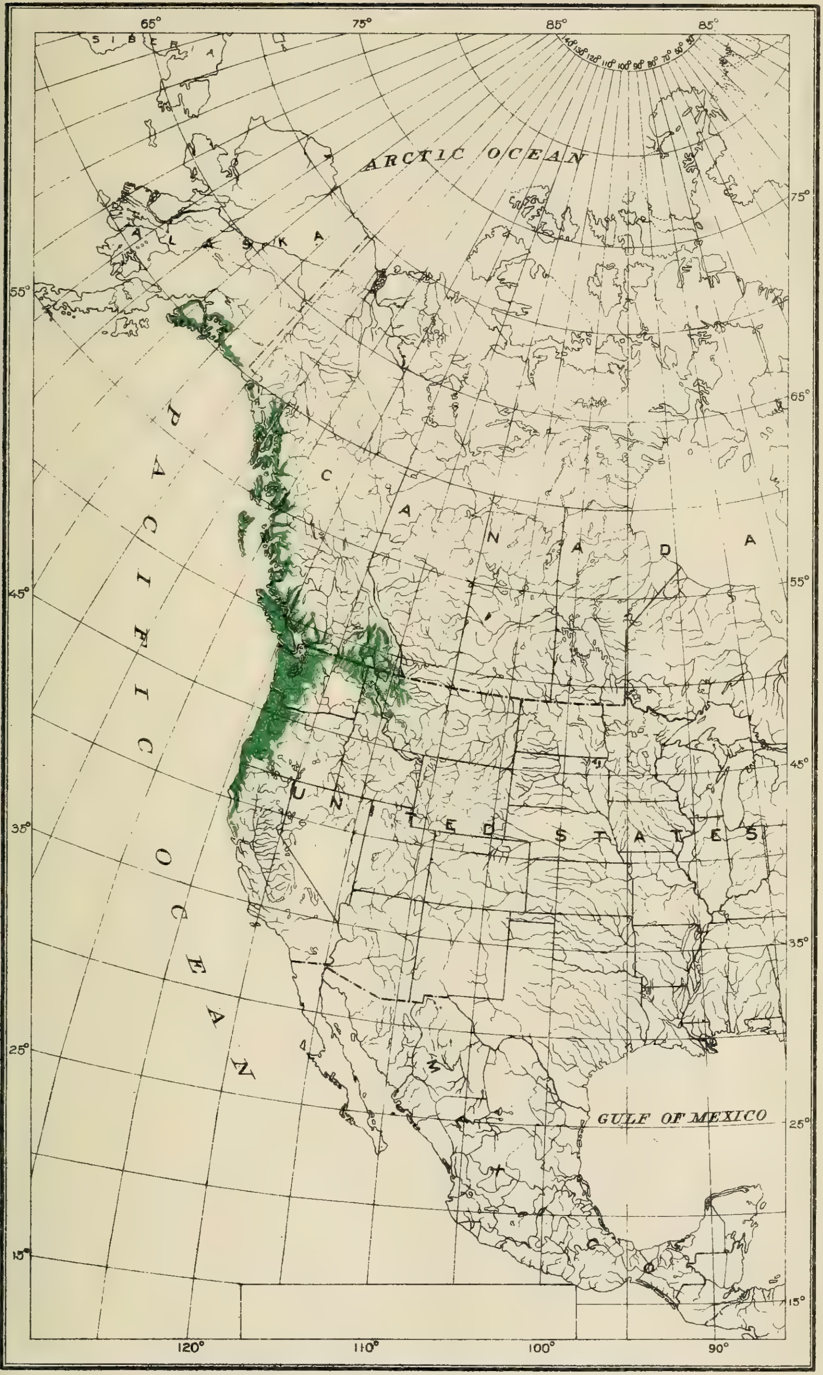

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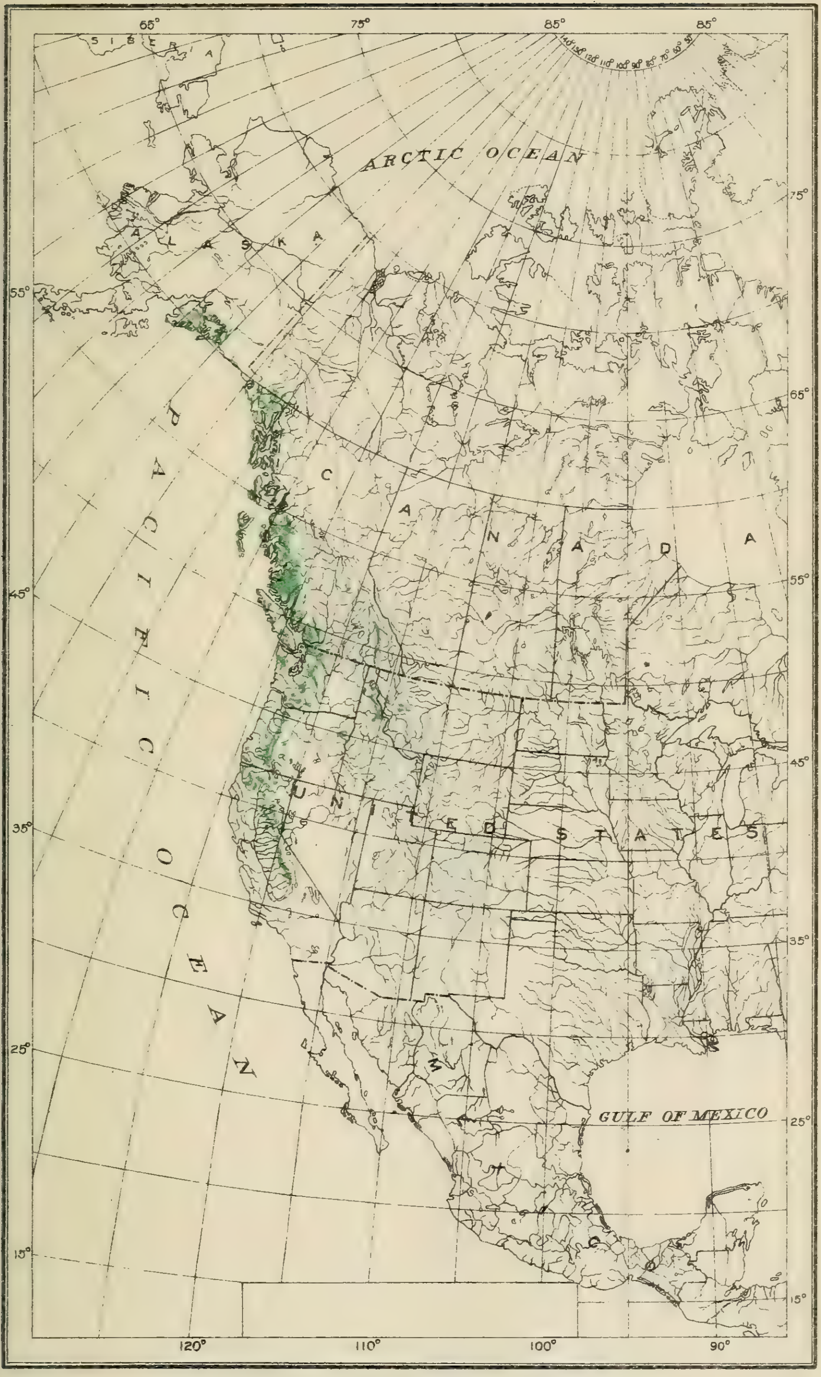
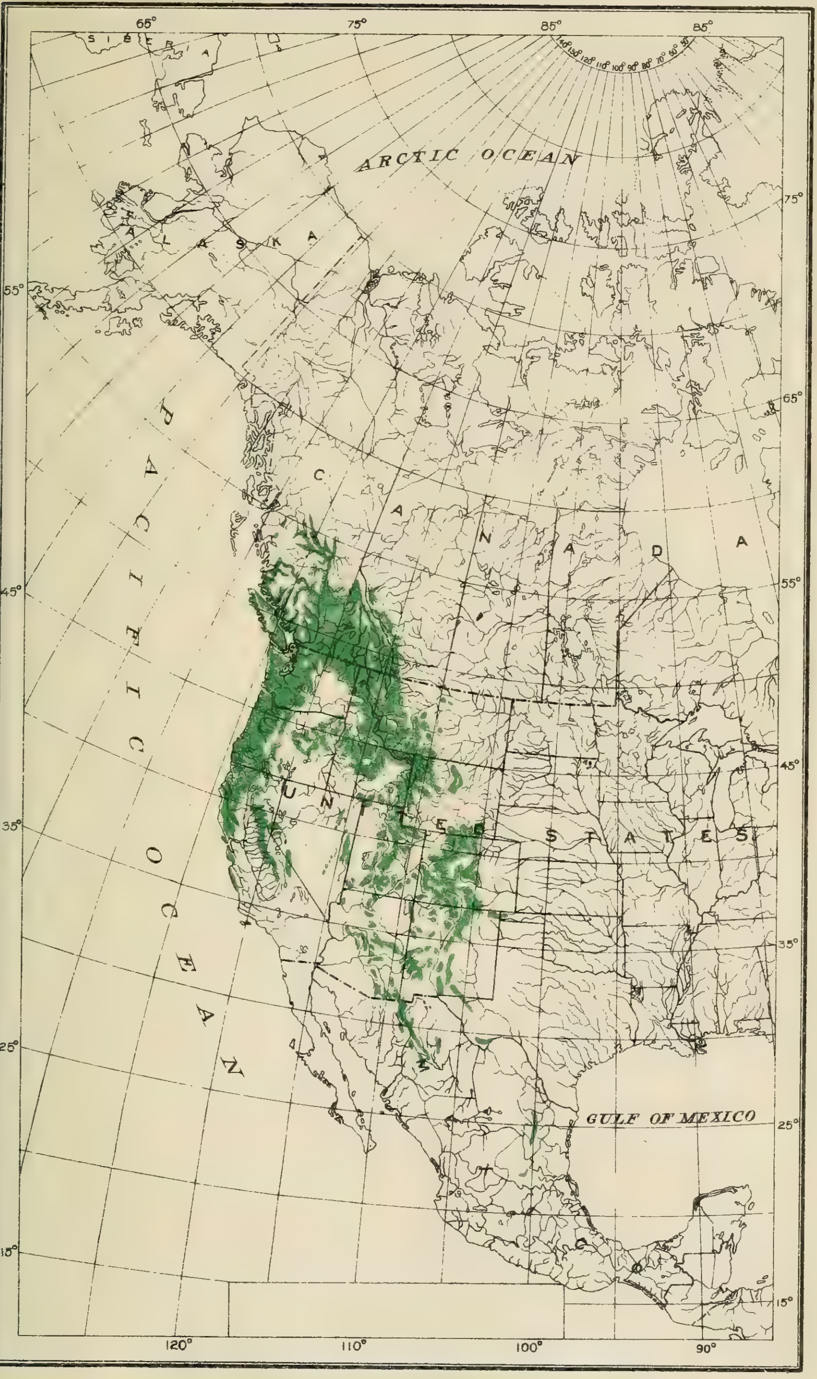


TSUGA MERTENSIANA: GEOGRAPHIC DISTRIBUTION.

MAP NO. 6.



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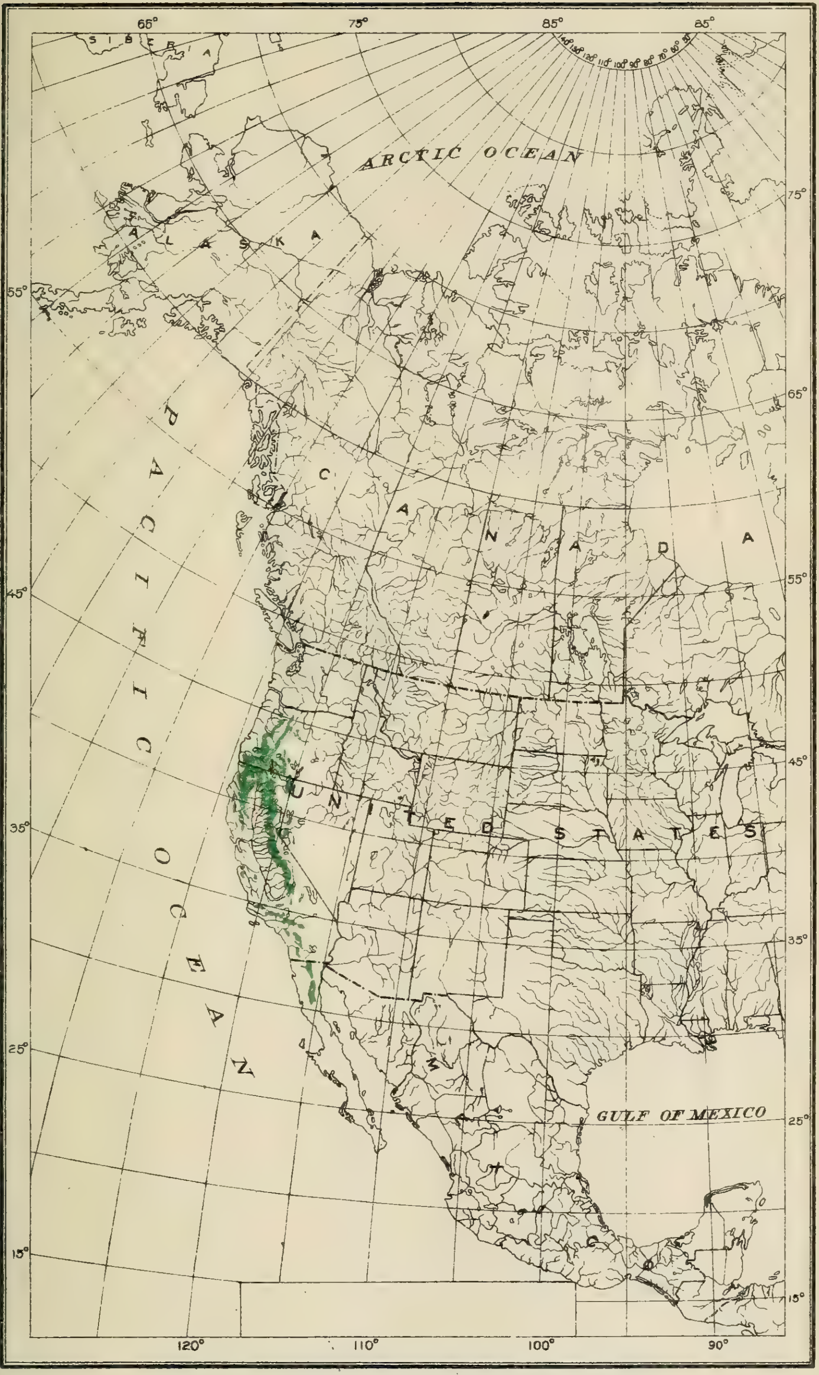

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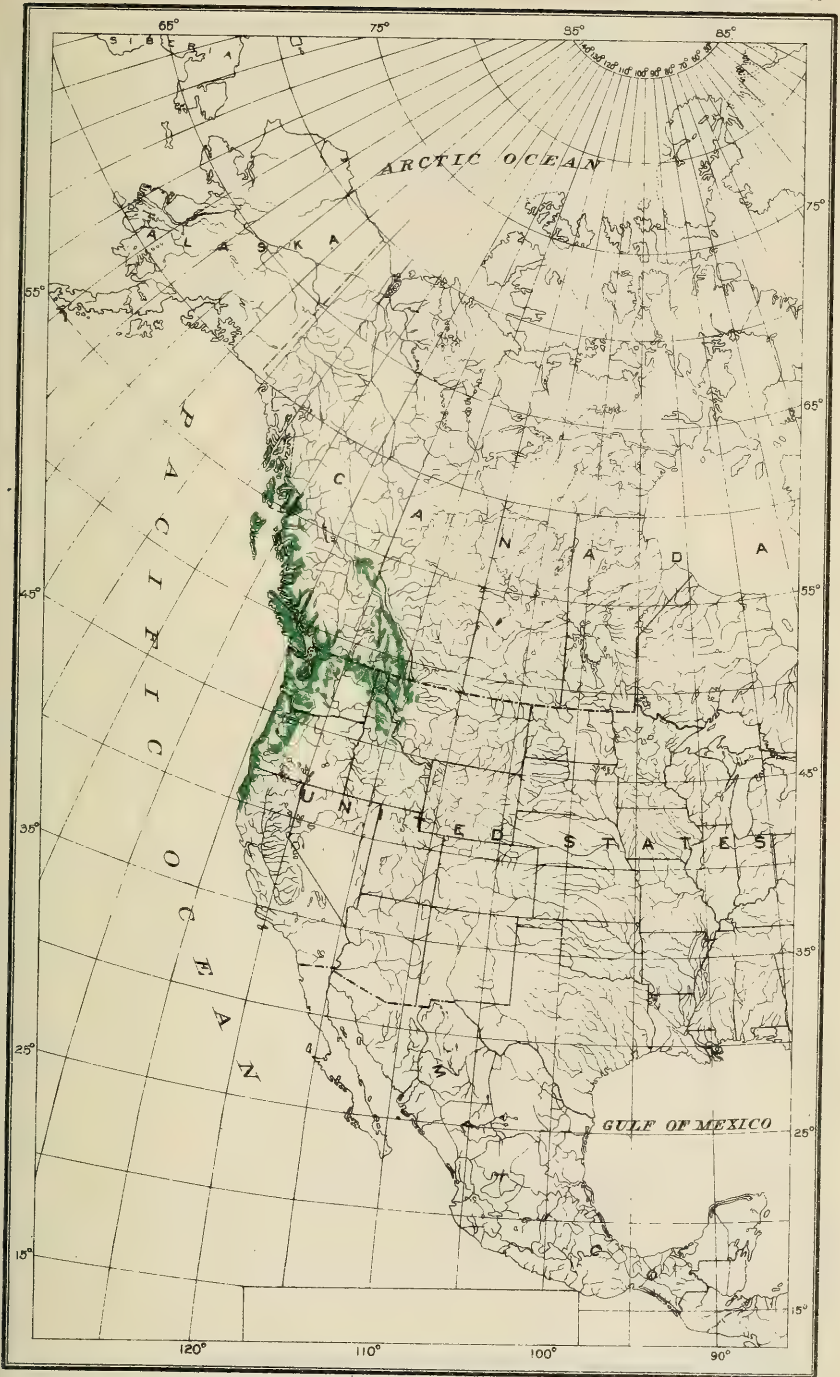

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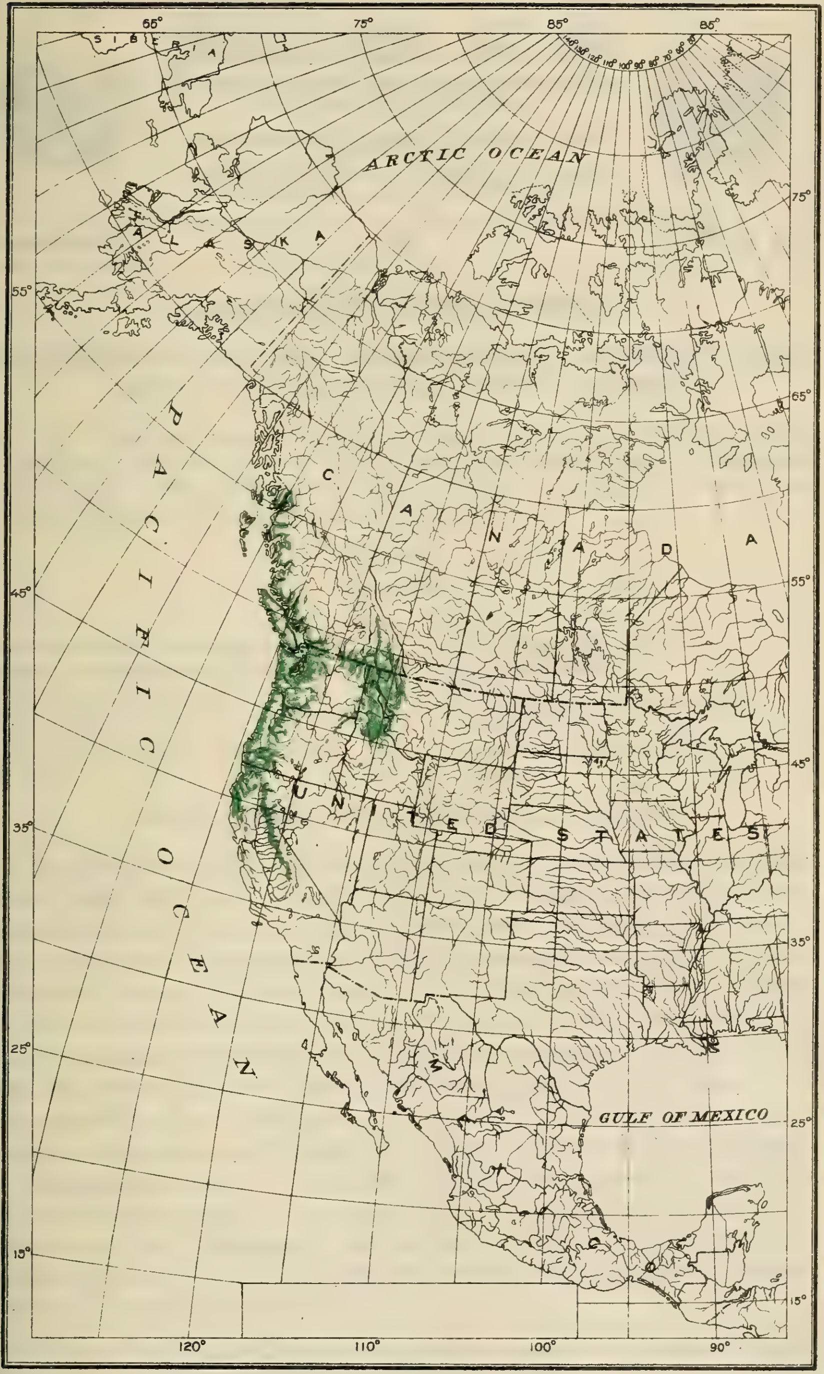

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Contribution from the Bureau of Chemistry, CARL L. ALSBERG, Chief,
And the Engineering Experiment Station, The Pennsylvania State College, R. L. SACKETT, Dean.

Washington, D. C. ▼ May 18, 1918

GRAIN-DUST EXPLOSIONS:

INVESTIGATION IN THE EXPERIMENTAL ATTRITION MILL AT THE PENNSYLVANIA STATE COLLEGE.[1]

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OBJECT AND SCOPE OF THE INVESTIGATION.

The great loss of life and property resulting from explosions in coal mines, flour and feed mills, grain elevators, thrashing separators, etc., emphasizes the fact that carbonaceous dusts are very inflammable and that careful laboratory and field investigations should be conducted in order to devise means for combating this great danger. Although Faraday in 1844 suggested that coal dust suspended in air would propagate an explosion, it has been recognized only within the past 30 years that coal dust is explosive without the presence of a combustible gas. And not only coal dust, but many other carbonaceous dusts are now known to be very inflammable and capable of propagating flames. Some idea of the large amount of attention that has been given to the explosibility of dusts can be gained by referring to the bibliography at the end of this bulletin (p. 52) and to that printed in Bureau of Mines Bulletin 20, which deals particularly with coal-dust explosions.

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[1] The erection of the mill and the conduct of the experiments were under the charge of B. W. Dedrick and R. B. Fehr, of the Department of Mechanical Engineering, assisted by P. X. Rice, R. E. Campbell, and E. F. Grundhoeffer, instructors in experimental engineering, and C. L. Charles, student assistant.

In June, 1913, an explosion in a feed-grinding plant in Buffalo, N. Y., caused the death of 33 men, injured more than 70 employees, and damaged a great deal of grain and property. Shortly afterwards the Bureau of Chemistry began its work in connection with dust explosions in grain mills, elevators, and industrial plants. During the period in which this study has been carried on a large number of disastrous dust explosions, in which many lives have been lost, large quantities of grain and food products destroyed, and much property damaged, have occurred in grain elevators, feed, cereal, and flour mills, starch factories, sugar refineries, and other industrial plants which handle grain. Several definite causes for these explosions have been established, and effective preventive methods have been developed and tested. At present the United States Department of Agriculture is conducting a special war-emergency campaign for the prevention of dust explosions and fires. Representatives of the department are rendering direct assistance to the millers and grain men of the country in installing devices for preventing explosions and in showing them how to remedy dangerous conditions.

The grain-dust explosion work, as conducted by the Bureau of Chemistry, falls into two general classes:

(1) Dust explosions which occur in grain mills, elevators, and industrial plants during the handling and milling of grains and the manufacture of food products.

(2) Dust explosions which occur in thrashing machines during the operations in the harvest fields.

MILL AND ELEVATOR EXPLOSIONS.

As soon as possible after the occurrence of an explosion in a mill or elevator, the field engineers of the bureau investigate carefully the conditions under which the explosion originated and assist the company to devise and install some means for preventing any more such explosions. During the course of these field investigations it has become apparent that one of the causes for a large number of dust explosions and fires in the cereal and feed mills, particularly in the feed-grinding departments, is the ignition of the dust on the interior of the grinding machine during operation. In many instances the evidence indicated that the explosion and fire originated within the machine, usually in the attrition type of mill. As they were believed to have been caused by sparks from foreign particles or metallic substances entering with the grain, the bureau emphasized the necessity for taking steps to remove these materials from the mill stream before it entered the grinding machines.[1]

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[1] Preliminary Report on the Explosibility of Grain Dusts, Cooperative Investigation by Millers Committee, Buffalo, N. Y., under the direction of Dr. George A. Hulett, chief chemist, Bureau of Mines, U. S. Department of the Interior, by David J. Price, engineer in charge, and Harold H. Brown, assistant chemist, Grain-Dust Explosion Investigations, Bureau of Chemistry, U. S. Department of Agriculture Copies no longer obtainable.

Early in the investigation it became obvious that experimental work was necessary to determine the circumstances under which the explosions and fires might originate and to establish definitely the possible causes. Because of the equipment available in connection with its milling course and its convenient location to Eastern mills, The Pennsylvania State College was selected as the best place for an experimental mill. This phase of the dust-explosion work was accordingly assigned to the experimental department of that institution, the experiments being conducted under a cooperative agreement between the Department of Agriculture and The Pennsylvania State College. The materials were furnished by various milling companies at the request of the department. This bulletin gives a description of the equipment of the mill, the manner in which the experiments were carried on, and the results obtained, together with an outline of conditions conducive to explosions in grinding machines and the effect of various preventive devices.

Aside from the relation of explosions and fires to grinding processes in the milling industry, the phase of the grain-dust explosion problem discussed in this bulletin, the department engineers have established a number of additional possible causes, among which may be mentioned: The use of open flames, lanterns, gas jets, etc., defective electrical equipment, frictional electricity produced by friction of pulleys and belts, choke-ups and friction in elevator legs, inefficient methods of dust removal and collection, and the continuance of dust rooms.

Recent investigations by the bureau have revealed the surprising fact that many of the owners and operators of large grain mills and elevators are unfamiliar with the circumstances surrounding grain-dust explosions, as a result of which dangerous conditions are permitted to exist. Recently a fire, originating in a dust explosion at the top of the elevator leg in one of the large grain elevators in the East, destroyed almost 1,000,000 bushels of grain. The present crisis makes it imperative that all known precautionary methods be adopted. The Department of Agriculture is therefore redoubling its efforts, and has arranged to conduct a special emergency campaign throughout the United States, to the end that grain dealers and millers may become familiar with the work already done. The field engineers will assist the millers and operators of grain elevators in the installation of preventive devices already developed by the Bureau of Chemistry.

THRASHING-MACHINE EXPLOSIONS.

The second division of the department's investigations into the matter of grain-dust explosions comprises an extensive study of thrashing-machine explosions, which has been confined largely to the States of Washington, Idaho, and Oregon.[1] During the past season the investigation has been extended to Colorado, Texas and other grain-growing sections.

THE EXPERIMENTAL ATTRITION MILL.

The investigations conducted with the experimental attrition mill were undertaken for (1) the determination of the possible causes of explosions, and (2) the testing of various preventive measures that have been suggested during the progress of the work. The entire scope of the investigation can be seen in the following outline of the various phases of the problem that were touched upon:

1. Sparks emitted by foreign substances.
2. Naked flame.
3. Carbon arc in attrition mill.
4. Carbon arc in dust room.
5. Explosibility of various grains.
6. Static electricity in attrition mill.
7. Static electricity as cause of explosions.
8. Effect of atmospheric humidity.
9. Effect of moisture content of materials.
10. Revolving dampers or fire traps.
11. Relief valve and pipe.

PRINCIPLES UNDERLYING GRAIN-DUST EXPLOSIONS.

On account of the general lack of knowledge concerning the theory of dust explosions it may be advisable to insert at this point a brief summary of the chief facts and principles involved.

It is generally conceded that two main conditions must be present in order that a dust may produce an explosion: (1) Fine, dry dust must be in a state of suspension in an atmosphere containing the proper amount of oxygen. (2) A source of sufficient heat must be brought in contact with the dust.

It should be noted that carbonaceous dusts are not considered capable of igniting spontaneously, for an outside source of heat is required. The following sources of heat have been listed as the probable causes of many of the explosions in milling plants throughout the country:[2]

1. Use of open lights, or naked flames, such as lamps, torches, gas jets, lanterns, candles, and matches.

2. Entrance of foreign material in grinding machines.

3. Electric sparks from motors, fuses, switches, lighting systems.

4. Static electricity produced by friction of pulleys and belts, grinding machines, etc.

As for the first condition, many factors are involved, such as the chemical composition, moisture content, fineness, atmospheric humidity, density or degree of diffusion, and presence of inert gases.

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[1] U. S. Dept. Agr. Bul. 379.

[2] Reference 27, Bibliography.

The Bureau of Chemistry is now conducting laboratory investigations of these factors, and has obtained data on the relative inflammabilities of various grain dusts, as well as on the use of inert gases. Briefly, the conclusions reached thus far are as follows:[1]

1. Most of the carbonaceous dusts have a higher degree of inflammability than Pittsburgh coal dust.
2. An inert gas mixture containing 12 per cent or less of oxygen will prevent a dust explosion from starting or propagating.

In 1913 R. V. Wheeler,[2] chief chemist for the Explosion in Mines Committee, England, published the report of his investigations of the relative inflammabilities of various dusts. He classified dusts as follows:

> 1. Dusts which ignite and propagate flame readily, the source of heat required for ignition being comparatively small, for example, a lighted match.
> 2. Dusts which are readily ignited, but which, for the propagation of flame, require a source of heat of large size and high temperature, such as an electric arc, or of long duration, such as the flame of a Bunsen burner.
> 3. Dusts which do not appear to be capable of propagating flame under any conditions likely to obtain in a factory, because they do not readily form a cloud in air, or are contaminated with a large quantity of incombustible matter, or the material of which they are composed does not burn rapidly enough.

Class 1.

Sugar.
Starch.
Rice meal and sugar refuse.
Wood flour.
Malt.
Oat husk.
Grain (flour mill).
Maize.
Grain (grain storage).
Rape seed.
Corn flour.
Flour (flour mill).

Class 2.

Rice milling.
Castor oil meal.
Offal grinding (bran).
Grist milling.
Corn meal.
Mustard.

Class 3.

Spice milling.
Cotton seed.
Cotton seed and soy bean.
Sack cleaning.
Rape seed (Russian).
Grain cleaning.

Available data show quite conclusively that there is a great similarity between gas and dust explosions. The following extract from an article[3] by H. H. Brown, of the Bureau of Chemistry, is of interest in this connection:

> It will be noted that just as high pressures have been observed in coal-dust explosions as in gas explosions. However, the extremely high velocities attained by the flame in certain gas mixtures have not been reported as observed in dust explosions. Such high velocities could not be expected, for even the finest dust particles are many times larger than gas molecules, and so, even in the most dense dust clouds, the particles could not be as close together nor as intimately mixed with the oxygen as are gas molecules. Therefore, the heat of combustion of one dust particle can not be as readily transmitted to the next particle as it can in a mixture of gases. But the finer the dust the more nearly will it approach the size of a gas molecule. Therefore, it

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[1] References 36 and 37, Bibliography.
[2] Reference 26, Bibliography.
[3] Reference 36, Bibliography.

might be expected that the velocity of the flame through a cloud of very fine dust would more nearly approach the velocity attained in gas explosions. As a matter of fact, this is true. Taffanel has brought this out in tests made at the French Experiment Station. Results obtained by the Bureau of Mines lead to the same conclusion.

The rate at which inflammation travels through a gas mixture is dependent upon at least two factors, the inflammability of the gas and the percentage of the gases in the mixture. The rate at which inflammation travels through a dust cloud seems to be dependent upon two similar factors, namely, the inflammability of the dust and the amount of dust in suspension. A third important factor is the fineness of the dust.

It will be seen, therefore, that gas and dust explosions are similar in many ways, and that a gas explosion is only a limited case of a dust explosion.

A thorough knowledge of the nature of dust explosions and of the accompanying phenomena is necessary in order to devise means for the prevention of such explosions and for the stoppage of explosions if by mischance they should start. It is, therefore, necessary to know how dust ignites, the various means by which it may be ignited or inflamed, and the chemical processes that take place. Another important factor to know is the ease with which the dust ignites and propagates a flame. This property we may call the "inflammability" of the dust. The term "explosibility" has also been applied in this connection..

It is important to note that investigations of dust explosions indicate that, in general, two reports are heard, the first being sharp and quick, and the second of a loud, rumbling nature and accompanied by more flame. It is thought that the first report is due to the ignition of a small quantity of fine dust in suspension, and that the resulting concussion is sufficient to disturb the dust that has settled at places farther away, thus forming an additional explosive mixture. The flame from the first explosion furnishes the source of ignition for this newly formed dust mixture, so that the big explosion with its loud roar is propagated throughout the entire dust zone.

APPARATUS USED IN THE INVESTIGATION.

For the purpose of conducting the experiments on grain-dust explosions a small, light frame building (15 by 15 by 24 feet), covered with galvanized iron, was erected by the Department of Mechanical Engineering, Pennsylvania State College (Pl. I). A small dust room was afterwards built at the side of the main structure at the discharge end of the screw conveyor. The grinding floor is elevated about 6 feet above the basement, which is level with the ground.

A 16-inch attrition mill (Pl. II) was installed on a platform 14 inches high, with a removable hopper underneath. Two elevators, one dump bin, a stock hopper over the mill, and a small bin for receiving ground materials were also provided. A screw conveyor 10 feet long was placed 2 feet below the floor to receive the material from the mill, and to carry it to the chop elevator or out into the dust room. The attrition mill, screw conveyor, and elevator are driven by a 15-horsepower direct-current motor, located in the basement.

The elevator legs and feed bin can be seen on the left of figure 1, Plate II. Immediately over the mill hopper are the spouts extending down from the stock bin and elevator. The removable hopper is partially withdrawn from under the mill platform. Above this hopper is one of the steel carbon holders entering the wooden door which has replaced the iron door of the lower part of the hood. In this wooden door is located a peephole, covered with mica, for the purpose of observing any sparks or flashes that may occur within the hood. On the opposite side of the mill (Pl. II, fig. 2) is a similar arrangement of peephole and carbon holder. The rheostat and ammeter for regulating the carbon arc, located on the edge of the hopper of the floor dump, are shown on the right. On the floor back of these instruments can be seen the recently installed relief pipe (R), leading from the hopper to the outside of the building, a distance of 8½ feet.

Plate III, figure 1, shows the dust room, located at the end of the conveyor, and the small door which gives access to the basement of the mill building. A small box (E) was built over the open end of the conveyor for the purpose of inclosing the carbon arc used in Series 4 (p. 14.) A relief pipe extends from this box up through the roof, and is capped by the hood (F).

Figure 1 gives a sectional view of the 16-inch attrition mill which was used for the tests described in this report. The grinding plates or disks (d_1 and d_2) revolve in opposite directions at about 2,200 revolutions per minute. The upper part of the hood or casing (c) inclosing the grinding disks can be readily removed. H is the feeding hopper where the grain is introduced and fed by a "wabbler," which is run by the friction pinion on the shaft (f). Horizontal slides within the hopper regulate the amount of feed. The adjustment of the fineness of grinding is accomplished by handwheels (1 and 2), the latter serving as a locking device. The tension spring (ts) holds

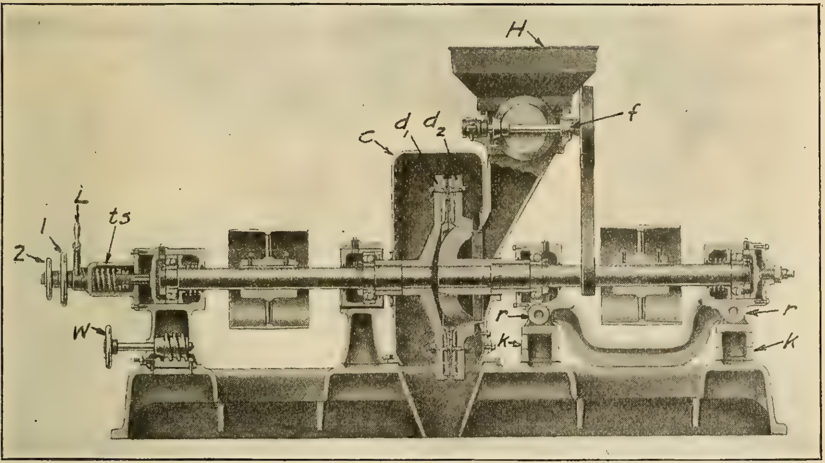

FIG. 1.—Sectional view of ball-bearing attrition mill.

the left disk in position, and acts as a safety appliance to allow the disks to separate in case hard substances pass through the mill. L is a quick-release lever for operating the spreading device.

Figure 2 is a diagrammatic view of the removable hopper (h) under the mill, spout (s), single revolving damper (installed for Series 8 and 9), and screw conveyor. The by-pass spout with its valve and peephole (C) was installed for the purpose of observing how far the flame due to an explosion may be propagated without the use of a "check" valve. B is a peephole for observing any flames that may pass the damper.

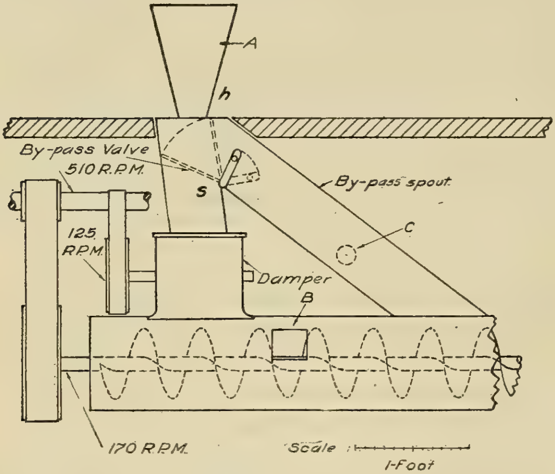

FIG. 2.—Elevation-attrition mill and conveyor. Single damper.

The construction of the single damper can be seen in figure 3, which gives the arrangement when two of these single dampers were placed in series, as in Series 11. As can be seen in the sectional view, the paddles or blades with their rubber "wipers," shown in black, are so arranged that there is never a clear path through the damper.

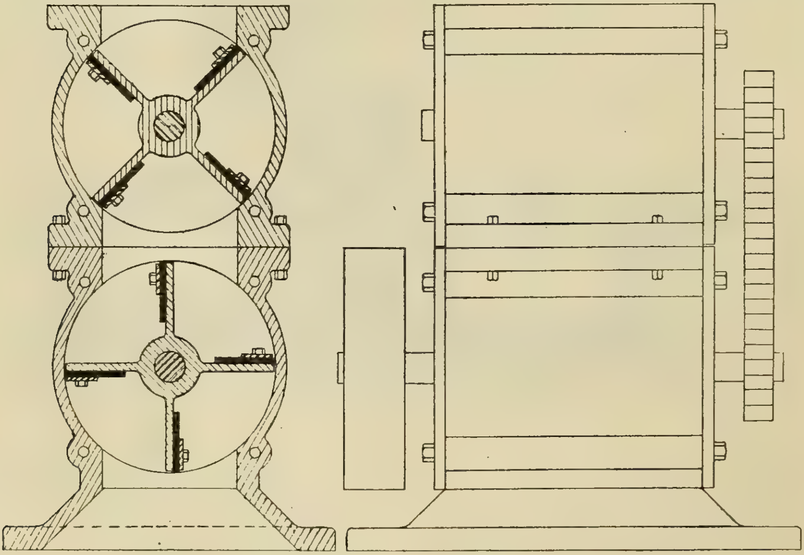

FIG. 3.—Views of double damper.

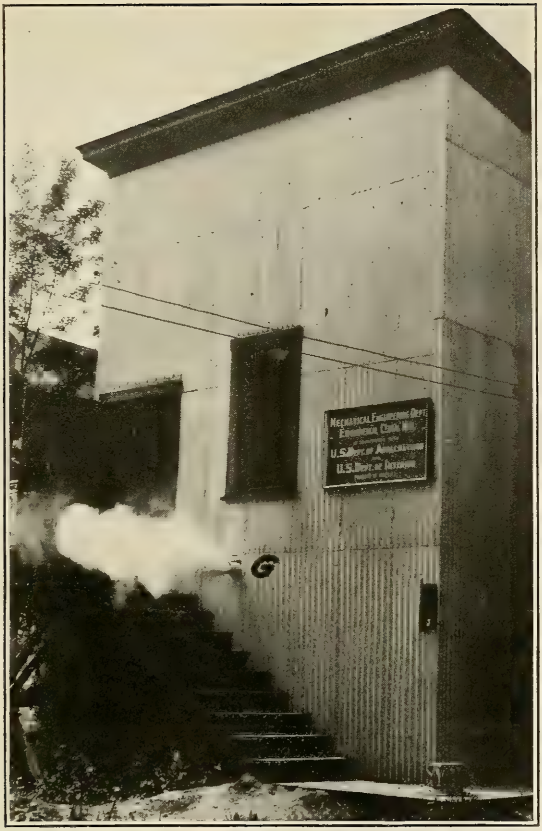

FIG. 1.

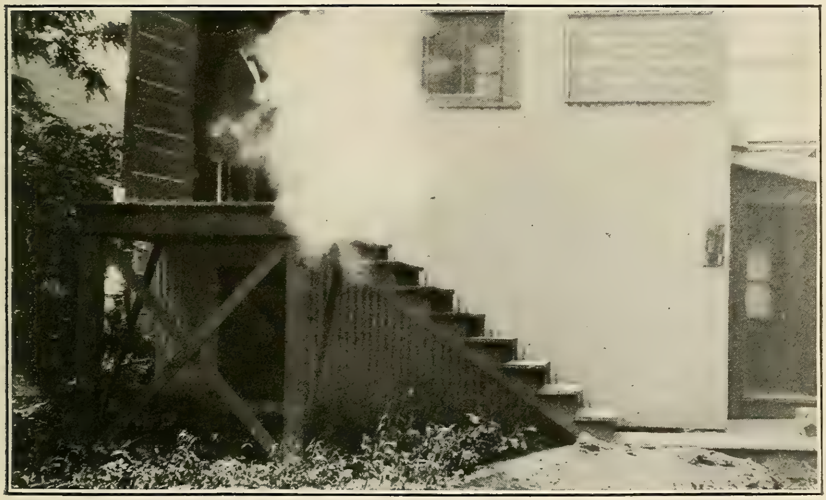

FIG. 2.

EXTERIOR OF EXPERIMENTAL MILL BUILDING.

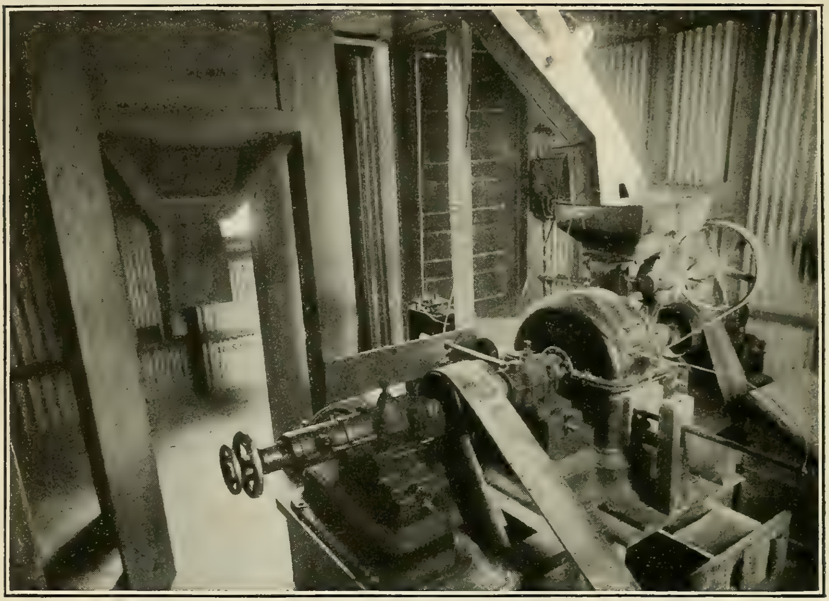

FIG. 1.

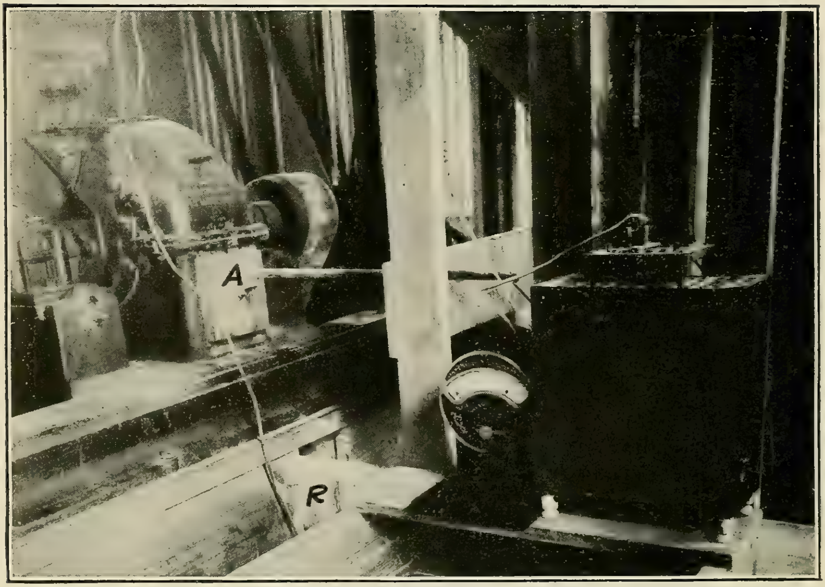

FIG. 2.

INTERIOR OF EXPERIMENTAL MILL BUILDING.

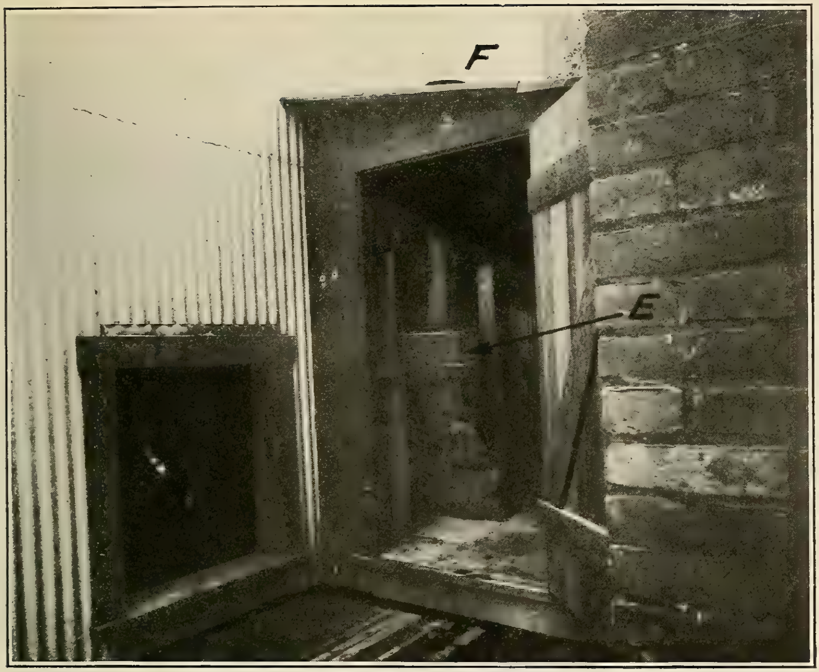

FIG. 1.—DUST ROOM.

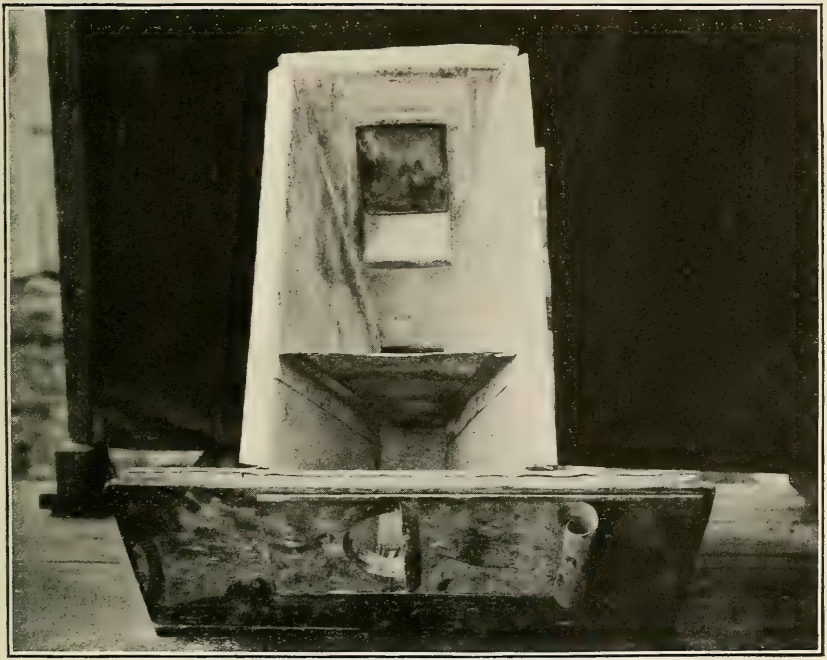

FIG. 2.—REMOVABLE HOPPER.

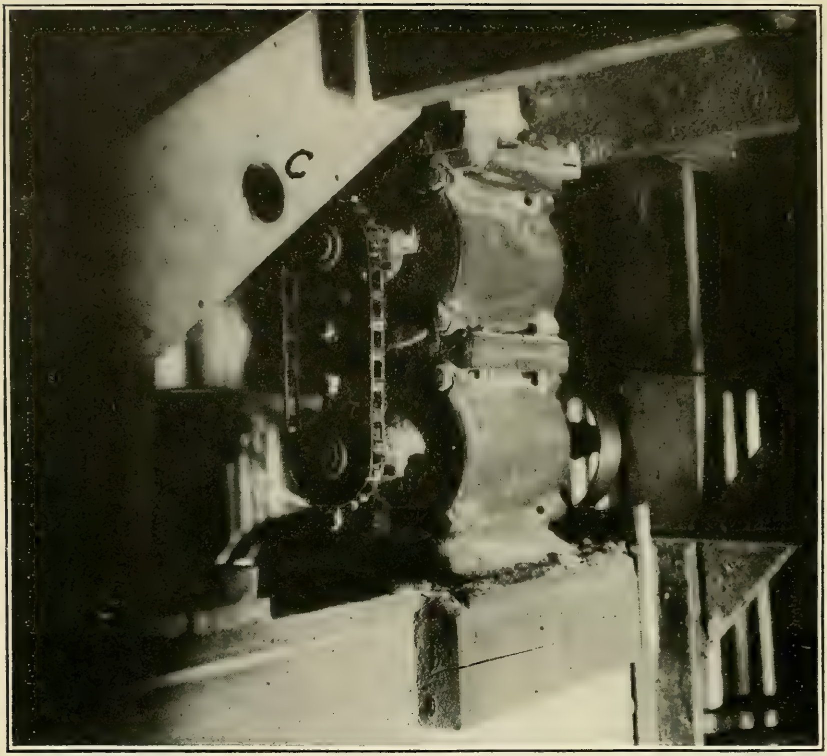

FIG. 1.—DOUBLE DAMPER.

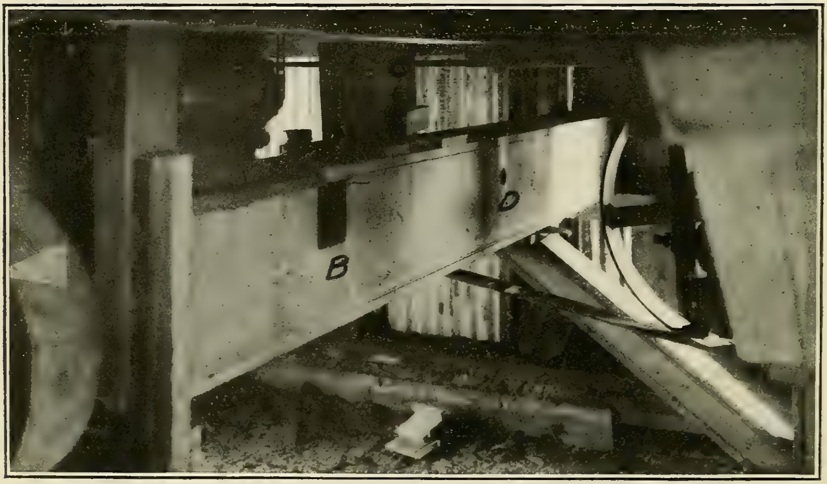

FIG. 2.—INTERIOR OF BASEMENT.

In figure 4, which is a diagrammatic view of the double damper and principal parts of the mill equipment, it is seen that the conveyor was lowered about 10 inches in order to make room for the double damper. Otherwise, the arrangement is practically the same as that in figure 2. The relief valve at A was installed with the relief pipe as explained in Series 13 (p. 18). The "spout to elevator," with its slide under the screw conveyor, shows how the ground material could be "recirculated," as stated in several series of tests, by means of the elevator and spouts shown in Plate II, figure 1.

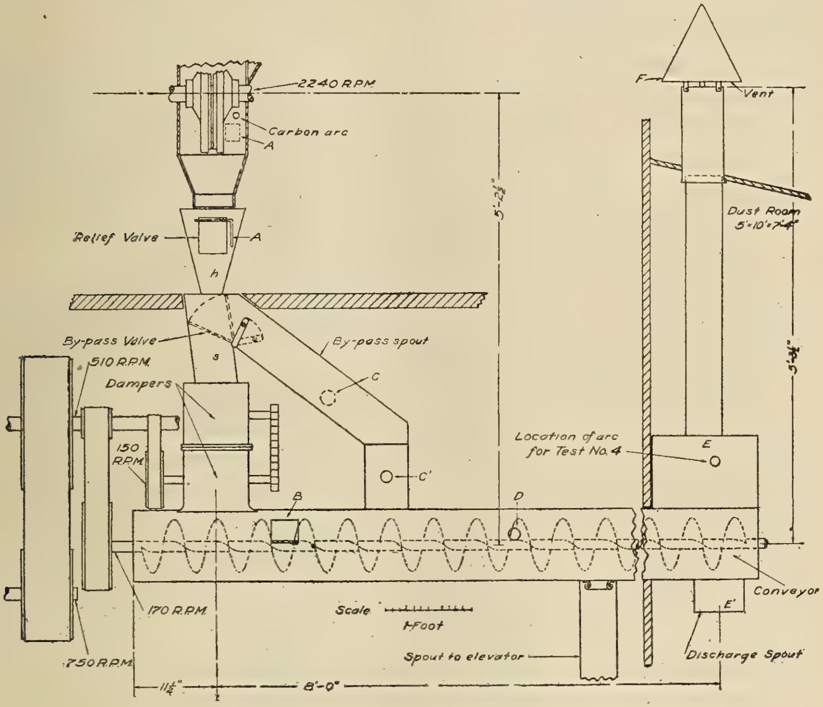

FIG. 4.—Elevation-attrition mill and conveyor. Double damper.

The two dampers were positively connected with each other by means of a chain and sprocket wheels (fig. 3) and were so arranged that they served as a double check for the flame propagated by explosion in the attrition mill. Plate IV gives two views of this double damper from opposite sides, figure 2 of the plate showing also the screw conveyor, peepholes, and spout leading to the boot of the meal or chop elevator.

Plate III, figure 2, shows the removable hopper, with the sheet-iron lining and swinging relief valve as installed for Series 13. This hopper was constructed so as to make a snug fit with the lower part of the hood of the attrition mill. When the hopper is in position under the attrition mill, the relief pipe (R) (Pl. II, fig. 2) can be attached to the stub spout containing the relief valve.

Plate I shows the puffs of smoke, dust, and charred particles that followed a flame issuing from the end (G) of the relief pipe when an explosion occurred in the attrition mill (Series 13).

MATERIALS USED IN THE INVESTIGATION.

DESIGNATION.	NAME.	DESCRIPTION.
A	Fine oat hulls	Oat hulls, finely ground in an attrition mill, millstone, or other grinding mill.
B	Elevator dust	Dust that has settled on machines, beams, etc., in a grain elevator. It is a highly inflammable dust of a very light and fine texture, and composed of floating carbonaceous material of grain, outer skins, together with foreign dust.
C	Oat hulls	The hulls stripped from oats, as in the preparation of oatmeal.
D_1	Flour, direct from store.	The interior or endosperm of any grain reduced to a very fine powdery state and free from the branny covering. It is composed mostly of starch, and is highly inflammable when in suspension.
D_2	Flour (oven dried)	Flour dried in an oven at about 150° F.
E	Graham flour	This is wheat which is ground but not bolted. It contains all of the flour, bran, and germy parts.
F	Wheat scourings	A fluffy and inflammable dust taken from dust collectors which are connected to the scouring or brush machines. It consists of foreign materials, such as dirt, smut, and portions of the light, thin, and loose outer skins of the bran.
G	Corn	Shelled corn.
H	Wheat shorts	Composed of the finer portions of bran, germ, and some floury material, separated from flour, in the process of milling.
I	Coarse floor sweepings	A coarser mill dust, settling on floor in immediate vicinity of mill.
J	Fine floor sweepings	The lighter and finer mill dust which settles in the room and outside the immediate vicinity of the attrition mill.
K	Conveyor mixture	A mixture of various materials as obtained from the end of the screw conveyor.
L	No. 2 feed dust	Consists of very fine particles of bran, fuzz, smut dust, and dirt, taken from the dust collector which draws air from the first scourer.
M	No. 1 feed dust	A material taken from the dust collector drawing the air through the second scourer. It consists almost entirely of the outer layers of the bran which have been removed by the scouring action of beaters.
N	Fine oat hull dust	This material is very finely ground oat hulls, brought out by the conveyor in the form of dust.
O	No. 3 elevator dust	Floating dust gathered by hand from the beams and machinery in the elevator.
P	Barley malt sprouts	Consists of barley malt sprouts that have been used as mash material and then dried.
Q	Malt sprouts	Consists of the radicles grown on the barley during the germinating process, and later broken off and dried.
R	Brewers' dried grain	This is the residue from a mash tub in a brewery or distillery, and consists of malt, corn, rice, hops, etc., which have been boiled and then dried.
S	Dried grain	This corresponds to "brewers' dried grain," except that the original mash consists of corn, barley, malt, and the radicles grown on barley during the germinating process, which are later broken off and dried.

EXPERIMENTAL WORK.

The results of the investigation are reported, first, by describing and summarizing briefly each one of the experiments performed, and, second, by discussing each one of the factors mentioned in the scope of the work (p. 12).

PRELIMINARY TESTS.

The experimental mill building at The Pennsylvania State College was completed in the spring of 1915, and the attrition mill, elevators, and conveyor were installed during the early part of the summer. During August several preliminary experiments were made for the primary purpose of ascertaining if explosions would result from the sparks emitted by foreign materials (nails, flint, matches, etc.) when passing between the grinding disks along with the grain.

At first the hood of the attrition mill was removed, so that the sparks emitted could be observed. When a single nail (eightpenny, but clipped to a length of about one-half inch) or small piece of stone was passed through the mill, sparks were, in nearly every case, emitted from different points of the periphery of the disks. Feeding 1 to 2 ounces of these clipped nails, small pieces of flint, or other hard materials, either singly or in combination, resulted in a large number of sparks, as in the case of an emery wheel. These sparks were thrown a distance of from 10 to 16 inches from the periphery of the disks. The sparks were emitted radially when both discs were running, and tangentially when one disk was stationary. When matches were fed into the mill, usually no sparks were emitted from the periphery of the disc, as the rapidly revolving arms of the disk generally ignited the matches before they had fairly entered the eye of the runner.

After making these observations of the sparks produced by foreign materials passing through the attrition mill, the hood was replaced, so that various kinds of grain products could be fed into the mill, with pieces of flint, nails, matches, etc. Three to five quarts of oat hulls, corn, elevator dust, flour, wheat scourings, wheat shorts, and floor sweepings were fed into the mill, at first singly, then in various combinations, with about 2 ounces of foreign materials, a quantity which probably would greatly exceed the amount of such materials finding their way into an attrition mill with the grain during a comparatively long period, under ordinary milling conditions. The disks were set very close in order to grind as fine as or even finer than is usual. Repeated attempts with such materials as flour, dried elevator dust, and dust settlings failed to produce a single explosion. Further efforts were made to obtain explosions by duplicating, as far as possible, the actual conditions obtaining in an attrition mill, by feeding the grain at normal rate until several bagfuls had been passed through. At frequent intervals pieces of nails, flint, etc., were added with the grain, but never was there the slightest evidence of an explosion.

The first explosion in the experimental attrition mill was obtained shortly after the preceding series of runs at the time when J. K. Clement, of the Bureau of Mines, was present to witness the tests. The bottom of the hopper was closed by the slide so as to retain the ground material and not permit any dust to escape except through the hand hole, which was open. When a quantity of elevator dust and ground oat hulls was fed into the mill, a rather dense cloud of dust issued from the hand hole, due to the fan-like action of the grinding disks. Upon placing a gasoline blow torch near this hand hole, the dust ignited and a flame, 6 feet long, shot out toward the wall. The hopper was immediately withdrawn, and about a quart of the same materials thrown into the mill, while the torch was introduced just within the space previously occupied by the hopper. A very thick cloud of dust was blown into the room. Immediately an explosion, or rather a large flame, occurred, followed by a second and more extensive one, covering nearly all the floor area of the dusty side of the building and extending almost to the roof. The door and windows were open. Otherwise, some damage might have resulted. As it was, the arms of the man who handled the torch were burned.

The results of these preliminary experiments (observed by J. K. Clement, B. W. Dedrick, M. P. Helman, J. Weaver, and F. Kline), may be summarized as follows:

1. More than 40 attempts with a total of from 3 to 5 pounds of foreign materials, such as nails, small pieces of stone and flint, and matches, fed along with various kinds of explosive grain products, failed to produce a single explosion.
2. Two attempts with a naked flame were successful in producing explosions.

EXPERIMENTS FROM APRIL 6, 1916, TO OCTOBER 3, 1917.

SERIES 1.

Object.—The object of the test was to determine whether explosions could be obtained by foreign materials capable of emitting sparks when ground, or by an electric arc located near the disks of the attrition mill.

Conditions.—The two removable iron doors of the mill were replaced by wooden doors, provided with peepholes covered with several layers of mica, and drilled for the insertion of iron carbon holders for the electric arc. The position of the arc could be shifted between the shaft and periphery of the disks, but it was soon found that its location did not seem to have any effect on the regularity of the explosions. As a rule, in this and succeeding tests, the arc was located nearer the shaft than the periphery. A rheostat and ammeter were provided for regulating the current (usually 15 to 20 amperes) through the arc. The hopper underneath the grinding disks was put in place, and its hand hole was left open so that the flash due to an explosion could be seen.

Results.—

1. Sparks from foreign materials did not cause an explosion.
2. The electric arc caused four explosions out of six attempts when large handfuls of feed were used.
3. Low rates of feeding did not produce an explosion with the electric arc.
4. Oat hulls, ground or unground, did not ignite, except when mixed with the highly inflammable elevator dust.
5. With elevator dust, when fed by the handful, either alone or with oat hulls, four explosions out of four attempts were obtained.

SERIES 2.

Object.—Same as that of Series 1.

Conditions.—Similar to those of Series 1, except that one of the disks was blocked so as to permit foreign substances, such as nails, to be in longer contact with the revolving disk and thus to give off more sparks. Definite amounts, usually 1 pint, of feed were measured out for the purpose of determining the limits of explosibility of various mixtures.

Results.—

1. In 21 attempts with the electric arc and various grains and mixtures, 16 explosions were obtained.

2. A mixture of 1 part elevator dust to about 8 parts of oat hulls appeared to be the limit of explosibility of these grain products.

3. When there was no opening the explosion was propagated to the outside end of the screw conveyor, as indicated by puffs of smoke (E in Pl. III, fig. 1, and in fig. 4).

4. Blocking one disk appeared to give results not different from those obtained when both disks were running.

5. Other results corroborated those of Series 1.

SERIES 3.

Object.—The primary object was to determine how far the flame was propagated from the source of the explosion.

Conditions.—The conditions of the test were similar to those of Series 2 (one disk being blocked), but the humidity was very high, inasmuch as there was a steady rain during a large part of the test. A 4 by 4 inch hole was cut in the upper part of the horizontal screw conveyor, about 1 foot from the chute leading down from the attrition mill and about 5 feet 4 inches from the shaft of the mill. The various kinds and mixtures of feed were prepared and measured into small paper bags, the contents of one of which were dumped into the feeding hopper at each attempt.

Results.—

1. Out of 39 attempts with the electric arc, 36 explosions occurred, in spite of the very damp atmosphere.

2. Explosions were obtained with elevator dust and oat hulls, and elevator dust, flour, graham flour, wheat scourings, floor sweepings, corn, and various mixtures of these substances.

3. The following classification of the 36 explosions may be made (Pl. III, fig. 1, and text fig. 2):

27 flashes were observed at B (5 feet 4 inches from shaft of mill).

9 flames were observed at E (12 feet 6 inches from shaft of mill).

3 flames were observed at F (17 feet from shaft of mill).

4. During the course of the tests the conveyor continually brought out smoldering lumps of ground products, which could be readily fanned into a red glow.

SERIES 4.

Object.—The object of this series of tests was to attempt to obtain an explosion in the dust room (located outside the building, at the end of the screw conveyor) and to determine if such explosion would propagate the flame back to the mill.

Conditions.—This dust room (5 by 10 feet by 7 feet high) was made as tight as possible, and the door was replaced by a heavy muslin curtain to retain the dust, at the same time permitting free expansion in case of an explosion. The electric arc was located at first in a small box built above the end of the conveyor, and later just outside this box. In both cases the arc was regulated by means of a long wooden pole extending to a safe point outside the building. The duct leading from E to the vent at F was removed (Pl. III, fig. 1). The hopper was placed under the grinding disks, and all holes, including B, were closed, in order to retain the dust as far as possible. Both disks of the attrition mill were run at their normal speed of 2,200 revolutions per minute. The arc was turned on, and various kinds of grain products, which had given explosions in previous tests, were run through the mill as rapidly as possible in order to get a large amount of dust into the dust room. After various grains had been fed for 15 minutes, a blast of burning dust was observed issuing from the outlet in the box above the conveyor. It was evident that the rapidly revolving attrition mill produced enough draft to force its dust out at the conveyor end without the use of a special fan. In fact, the force of the blast was so great that it did not appear possible for the flame to get back to the attrition mill. The flame was extinguished by merely turning off the arc, and then more elevator dust was rapidly fed into the mill, the arc having been turned on again. Within 2 minutes, another heavy blast of flame was observed at the end of the conveyor. In this instance the flame could not be extinguished by turning off the arc, because the wooden box on the end of the conveyor had caught fire. The mill was stopped immediately, and the burning box saved by means of a fire extinguisher. After the arc had been placed just outside this box the mill was run again. Elevator dust and ground oat hulls were fed for 15 minutes, during which time the room became very dense with dust. Although the arc had been burning during this time, no explosion occurred, but, as before, due to the intense heat radiating from the air, the box over the end of the conveyor was again on fire. The mill was stopped, and the fire easily extinguished with a pail of water.

Results.—No explosions were obtained in the dust room by means of an electric arc in this series of tests.

SERIES 5.

Object.—This test was run as a demonstration to Government officials from the Bureau of Mines (G. A. Hulett and J. K. Clement) and from the Bureau of Chemistry (D. J. Price, H. H. Brown, and W. G. Goodenow).

Conditions.—The arc was located near the disks, which were run at their normal speed. Various kinds of grain products (except elevator dust, the supply of which had been exhausted) were fed into the attrition mill.

Results.—Although explosions were readily obtained with flour and wheat scourings, none was obtained with corn, as in Series 3. In fact, the regularity and force of the explosions, none of which caused the flame to extend as far as the end (E) (Pl. III, fig. 1) of the conveyor, were not nearly as great as in Series 3, in spite of the relatively low humidity (49 per cent) of Series 5, as compared with other tests.

SERIES 6 AND 7.

Object.—These experiments were run to determine whether an explosion would result from the discharge of static electricity.

Conditions.—The conditions of testing were similar to those of previous tests with the electric arc. The carbons were replaced by ¾-inch brass balls screwed on the ends of long ¼-inch iron rods, which replaced the ¾-inch iron carbon holders. These ¼-inch rods were inserted through porcelains in the wooden door of the hood, to insure insulation from the metal frame of the machine, and were connected by 15-foot leads to the poles of a small Wimshurst machine.

Results.—Under normal conditions this machine was capable of producing a good spark about 3 inches long, but under the conditions of the test, with the long leads, and great leakage, it gave only a very weak spark, hardly more than ½ inch long, between the brass knobs near the disks of the mill. It was, therefore, decided to make use of an induction coil instead of the static machine. By this means a very hot and almost continuous spark 2 inches long could be obtained between the brass knobs. On two different days a total of 20 attempts was made to obtain explosions with various inflammable dusts by means of the spark from an induction coil. The spark gap was varied from ½ to 1¾ inches. No explosions occurred. This negative result, of course, does not indicate that static electricity can not cause an explosion in an attrition mill, but rather that under the particular conditions of the test, the mixtures of air and dust were not sufficiently inflammable to be ignited by the sparks from an induction coil. In order to show that the electric arc, on account of the greater amount and intensity of heat produced, could ignite the same mixtures under the same conditions, the carbons were quickly substituted for the brass knobs, and then within 10 minutes of Series 7, a number of explosions was obtained in Series 8 with the same substances by means of the electric arc.

SERIES 8 AND 9.

Object.—The object of these tests was to note the effect of a single revolving damper in preventing the propagation of explosions occurring in an attrition mill.

Conditions.—The revolving damper was installed as shown in figure 2. The details of this damper may be seen in figure 3, which shows two such dampers in series. The by-pass and butterfly valve were inserted to make certain that the flame would be propagated that far when the damper was off, or out of service.

Results.—

1. Total number of attempts to obtain explosions with arc	73
2. Total number of explosions	57
3. Damper in service during explosion	29
4. Damper out of service during explosion	28
5. Flashes of flame in by-pass (damper off)	11
6. Flashes of flame at end of conveyor (damper on or off)	0
7. Puffs of smoke at end of conveyor (damper off)	21
8. Flashes of flame past damper when in service	6
9. Puffs of smoke at end of conveyor (damper on)	0

SERIES 10.

Object.—To determine whether static electricity was built up during the operation of an attrition mill.

Conditions.—For this purpose a sensitive gold-leaf electroscope was procured from the Department of Physics. The collecting devices consisted of a comb made up of pins and tin foil located near one of the driving belts and of two 5-foot flexible lamp cords with 3-inch pieces of No. 14 bare copper wire soldered to each end. During the tests the casing of the electroscope was grounded by being held in the hand, while the binding part of the gold leaf was connected by the flexible wire lead to the collecting comb, or any part where it was desired to test for static electricity. The attrition mill was run at its normal speed of 2,200 revolutions per minute.

Results.—See Table 10, page 29.

SERIES 11.

Object.—To note the effect of a double damper in preventing the propagation of explosions.

Conditions.—The single damper used in Series 8 and 9 seemed to retard to a marked degree the propagation of explosions occurring in the attrition mill, but did not always prevent the flame from getting past the damper. Consequently, a double damper (figs. 3 and 4 and Pl. IV) was installed, with a view to checking any flame that might pass the first set of revolving paddles. Incidentally the mill was run several hours while oat hulls were fed at as great a rate as possible. The ground oat hulls were conveyed back into the mill in order to produce as much dust as possible. For over an hour the electric arc was turned on, but not a single explosion resulted.

Results.—

1. During the operation of the attrition mill under severe conditions as to rate of feeding and source of ignition no explosion could be obtained with oat hulls during a period of over an hour.
2. Out of six explosions with the dampers in service two flames shot past B and D (fig. 4).
3. In two instances with the dampers in service smoke was observed issuing from the end of the conveyor, but without any force.

SERIES 12.

Object.—Same as that of Series 11.

Conditions.—Similar to those of Series 11, except that the oat hulls used during the preliminary run had been fairly well dried by being spread out in shallow pans, which were then placed on top of radiators for a period of several days. Thus the moisture content was reduced from 9.9 to 3.2 and 5.7 per cent.

Results.—

1. Only one explosion was obtained during the continuous grinding of fine oat hulls.
2. In each of the four explosions with the double damper in service a flame got past the damper and in three cases extended as far as D.
3. In no instance was a flame observed at the end of the conveyor.
4. Smoldering lumps of ground products were found to be very dangerous, in that they set fire to the wooden base of the attrition mill.

On account of the fire hazard involved in these smoldering lumps of grain, special emphasis should be placed on this result of Series 12. During this series of tests it was observed that smoldering lumps, resulting from the explosions, were frequently brought out by the screw conveyor. Some of these lumps happened to be placed on several layers of asbestos paper. After several minutes it was observed that a hole had been burned through the asbestos paper. Even when this smoldering material was buried under several inches of grain it continued to burn, although not as well as when it was spread out in a thin layer and exposed to the atmosphere. That this smoldering material was to be regarded as a great source of danger was very forcibly demonstrated when on the following morning it was discovered that the wooden platform and floor near the removable hopper of the attrition mill had been set on fire, evidently by some smoldering grain that had not been removed after the experiments of the preceding day. This result strongly suggests a greater use of sheet iron, or other noncombustible material, in milling plants.

SERIES 13.

Object.—The object of this experiment was to note the effect of a pressure-relief pipe.

Conditions.—It had been suggested that a means for automatically relieving the pressure, due to an explosion, might aid materially in preventing the propagation of the flame to a dangerous part of the mill. Accordingly, a device (Pl. II, fig. 2, and Pl. I, fig. 1) consisting of a pipe 5 inches in diameter and 8½ feet long, with a rectangular end containing a light sheet-iron relief valve, which remained closed by its method of overhead suspension (fig. 3), was installed. This end of the relief pipe was inserted in the hopper (Pl. III, fig. 2), which had been lined with galvanized iron on account of the many fires that had occurred in the wooden hopper.

Results.—

1. In nearly all of the 14 explosions with the damper in service a flame and puff of smoke were observed at the end of the relief pipe (G), indicating that the relief valve opened properly.

2. In four out of eight instances, however, flames were observed getting past the double damper. although never as far as the conveyor end.

SERIES 14 AND 15.

Object.—The primary object of these last experiments was to determine whether certain grain products, such as oat hulls, containing considerable dust, barley malt sprouts, malt sprouts, brewers' dried grain, and "dried grain," all of which had been recently received from various manufacturers, would give an explosion under severe conditions in an attrition mill. Incidentally, observations were made of the effects due to the relief pipe and double damper.

Results.—

1. By means of the electric arc, explosions were obtained with dusty oat hulls, malt sprouts, barley malt sprouts, brewers' dried grains, and various mixtures (Table 16).

2. Out of 45 explosions with the damper in service, four flames passed the damper, one of them extending as far as the end of the screw conveyor.

3. In all cases of explosions, puffs of smoke were observed at the end (G) of the relief pipe (Pl. I, fig. 1).

TABULAR STATEMENT OF RESULTS OBTAINED AT THE ATTRITION MILL.

TABLE 1.—*Series 1. Explosions with electric arc.*[1]

Time.	Explosion No.	Feed.	Ignition.	Observation of explosion.	Temperature.		Humidity.		Remarks.
					In.	Out.	In.	Out.	
a. m.					*° F.*	*° F.*	*Per ct.*	*Per ct.*	
10.00					55	49		72	Started mill and brought it up to full speed, 2,200 revolutions per minute.
10.05									Started feeding oat hulls.
10.20		Ground oat hulls	Arc	Nothing	57	51			Large handful of feed at each attempt.
10.30		do	do	do	58	51	51		
10.45		do	Stones, nails	Nothing (several attempts)	59	53		47	
11.00	1	Elevator dust	Arc (intermittent)	Flash through hopper handhole; flame 6 feet long.	59	53			
11.15	2	Mixture fine oat hulls and elevator dust.	Arc	Explosion of more force; flame spread more.	59	51	40		
11.30	3	Elevator dust	do	Explosion like that in explosion 2.	59	51	44		
11.32	4	One-fourth oat hulls and sweepings, three-fourths elevator dust.	do	Explosion heaviest of all					
Summary:		6 attempts		4 explosions.					

[1] The arc was located near the shaft and disks, and drew from 15 to 20 amperes.

Date: April 6, 1916.
Weather: Cloudy, but bright; no wind; 51° F.
Observers: R. L. Sackett, B. W. Dedrick, R. B. Fehr, B. J. Culp, H. R. Brown.

TABLE 2.—*Series 2. One disk blocked.*

Time.	Explosion No.	Feed.	Ignition.	Observation of explosion at mill.	Temperature.		Humidity.		Remarks.
					In.	Out.	In.	Out.	
a. m.					*°F.*	*°F.*	*Per ct.*	*Per ct.*	
10.00		Elevator dust	None	Handhole of hopper open	56	53	82		Started mill.
10.10	1	1 pint elevator dust	Arc	Explosion					
10.12		do	Arc (int.)	Nothing					
10.15		do	Flint and nails	do			70		
10.16	2	1 pint 1:1 mixture elevator dust and oat hulls.	Arc	Explosion					
10.20	3	1 pint 1:2 mixture elevator dust and oat hulls.	do	Small flame				87	
10.25	4	do	do	Large flash					
10.30	5	1 pint 1:3 mixture elevator dust and oat hulls.	do	Explosion	58	53	70		
10.35	6	1 pint 1:4 mixture elevator dust and oat hulls.	do	do					
10.38	7	do	do	do					
10.40	8	do	do	do					
10.43	9	1 pint 1:5 mixture elevator dust and oat hulls.	do	Large flash					
10.46	10	1 pint 1:7 mixture elevator dust and oat hulls.	do	do					
10.49		1 pint 1:9 mixture elevator dust and oat hulls.	do	Nothing					
10.50		do	do	do					
10.51		do	do	do					
10.55	11	1 pint elevator dust	Arc (int.)	Very large flame in very dusty room.					
10.58									Handhole of hopper was closed. End of conveyor in outside dust room only opening.
11.00	12	1 pint elevator dust	Arc	Flash	60	53	75		Puff of smoke at end of conveyor.
11.02	13	do	do	Larger flash					Do.
11.07	14	1 pint conveyor product	do	Heavy explosion					Large puff of smoke at end of conveyor.
11.10	15	Same as No. 5	do	do					Do.
11.13	16	Same as No. 10	do	do					Do.
11.15		1 pint oat hulls	do	Nothing					Shut down mill.
Summary:		21 attempts		16 explosions.					

Date: April 13, 1916.
Weather: Cloudy; no wind; 53° F.
Observers: B. W. Dedrick, R. B. Fehr, B. J. Culp, H. R. Brown, R. E. Campbell, H. H. Colbus.

TABLE 3.—*Series 3. Flame propagation.*

Time.	Explosion No.	Feed.	Ignition.	Observations.			Remarks.
				A.	B.	E.	
a. m. 9.25							Started mill. Temperature (inside), 65° F. Humidity (inside), 82 per cent.
9.30	1	1 pint elevator dust	Arc	Puff	Puff	Puff	
9.35							Shut down to repair belt.
9.55							Started again.
10.00	2	1 pint elevator dust	Arc	Very large puff	Flash	Puff	
10.03	3	do	do	Heavy puff	Puff	do	Disks not together.
10.05		do	do	Nothing			Do.
10.06	4	1 pint 1:2 mixture elevator dust and oat hulls.	do	Heavy puff	Puff	Puff	Do.
10.08	5	1 pint 1:7 mixture elevator dust and oat hulls.	do	Puff	Flash	do	Disks together.
10.10	6	1 pint flour	do	Light puff	do	do	
10.12	7	1 pint graham flour	do	Puff	do	Flame	Most violent of any explosion so far.
10.14	8	1 pint flour	do	do	do	do	Very good.
10.16	9	do	do	do	do	Smoke	
10.20	10	do	do	do	do	do	
10.22	11	1 pint 1:1 mixture flour and elevator dust.	do	do	do	do	
10.24	12	1 pint wheat scourings	do	do	do	Much smoke	
10.26	13	do	do	do	do	do	
10.27	14	1 pint corn	do	Set hopper on fire	do	Flame	
10.28	15	do	do	Puff	do	Smoke	
10.30	16	do	do	do	do	Flame	
10.32		do	Flint	Nothing			
10.35		do	Nails	do	Sparks		
10.36	17	1:1 mixture corn and elevator dust	Arc	Puff	Big flame	Big flame	
10.38	18	do	do	Big flare	No flame	No flame	
10.39	19	1:2 mixture corn and elevator dust	do	Puff	Flash	Smoke	
10.45							Steady rain. Temperature (inside), 60° F. Humidity (inside), 97 per cent.
10.50		1:1 mixture corn and elevator dust	Matches	Nothing			
10.52		Elevator dust	do	do			
10.53	20	1:1 mixture corn and elevator dust	Arc	Big puff and flame	Flash	Smoke	
10.55	21	do	do	do	do	Flame	Flame at top of air duct (F).
10.56	22	Corn	do	Puff	do	do	
11.02	23	Flour, corn, and elevator dust	do	do	do	Smoke	

TABLE 3.—*Series 3. Flame propagation*—Continued.

Time.	Explosion No.	Feed.	Ignition.	Observations.			Remarks.
				A.	B.	E.	
a. m.							
11.04		Plain wheat shorts	Arc	Nothing			
11.05	24	1:2 mixture corn and flour	do	Puff	Flash	Smoke	
11.07	25	Flour	do	do	do	do	Outside temperature, 51°F.
11.10		do	do	Nothing			
11.12	26	Coarse floor sweepings	do	Puff	Smoke	Smoke	
11.14	27	do	do	do	do	do	
11.15	28	Fine floor sweepings	do	do	Flash	Big flame	
11.17	29	do	do	do	do	do	Flame at top of air duct (F).
11.19	30	do	Arc (int.)	do	No flash	No flash	
11.20	31	do	do	do	Flash	Big flame	Flame at F.
11.22	32	Coarse sweepings	do	do	Puff	Puff	
11.23	33	Conveyor mixture	Arc	do	Flash	do	
11.24	34	do	do	do	2 flashes	do	
11.25	35	do	do	2 puffs	Flash	do	
11.26	36	do	do	do	do	do	Still raining. Outside temperature, 52° F.
Summary:		43 attempts (39 arc, 4 foreign material).		36 explosions (27 flashes, 9 flames).			

Date: Apr. 14, 1916.
Weather: Steady rain; no wind; 51° F.
Observers: B. W. Dedrick, R. B. Fehr, B. J. Culp, H. R. Brown, R. E. Campbell, H. H. Colbus.

TABLE 4.—*Series 4. Electric arc in dust room (5 by 10 by 7 feet).*

Time.	Observations.	Remarks.
a. m. 9.00		Started mill. Fed corn, flour, floor sweepings. Arc located in box over end of conveyor.
9.15	Blast of burning ground products issuing from outlet of box containing arc	Fed elevator dust. Flame extinguished by turning off the electric current through the arc.
9.18		Fed more elevator dust and turned on arc.
9.20	Blast of flaming dust, which continued when arc was turned off. Wooden box containing arc caught fire.	Fire extinguished by "pyrene." Mill shut down.
9.35	Room dense with dust, but no explosion	Mill started. Arc just outside box, in dust room. Elevator dust fed for 10 minutes.
9.45		Fed ground oat hulls for 5 minutes.
9.50	Fire in box over end of conveyor	Extinguished by water. Mill shut down.
Summary:	No explosion due to electric arc in dust room. Dust from end of conveyor on fire three times.	Wooden box at end of conveyor on fire twice (due to arc).

Date: Apr. 18, 1916.
Weather: Clear; very windy; temperature, 53° F.; humidity, 31 per cent.
Observers: B. W. Dedrick, R. B. Fehr, B. J. Culp, R. E. Campbell.

TABLE 5.—*Series 5. Demonstration for Government officials.*

Time.	Observations.	Remarks.
a. m. 11.00		Started mill, to get it warmed up.
12.00		Started arc.
p. m. 1.30	Explosions readily obtained with flour and with wheat scourings, but none with corn. No indication of flame shooting out of end (E) of conveyor, as in Series 3.	Started demonstration. Fed all the kinds of grain dust previously tried, except elevator dust, the supply of which had become exhausted.
2.15	Fire in hopper, floor and conveyor	Mill shut down.

Date: May 19, 1916.
Weather: Clear; slight breeze; temperature, 67° F.; humidity, 49 per cent.
Observers: G. A. Hulett, J. K. Clement, H. H. Brown, D. J. Price, R. L. Sackett, W. G. Goodenow, B. W. Dedrick, R. B. Fehr, B. J. Culp, H. R. Brown.

TABLE 6.—*Series 6. Preliminary test with induction coil.*

Time.	Feed.	Length of spark.	Observations.	Remarks.
p. m.		*Inches.*		Carbons of previous experiments were replaced by $\frac{3}{4}$-inch brass balls connected with an induction coil capable of producing a spark 2 inches long, directly under shaft.
2.20				Started mill.
2.30	1 pint flour	$1\frac{1}{2}$	No explosion.	
	2 pints flour	$1\frac{1}{2}$	do	
	1 pint flour	1	do	
	2 pints flour	1	do	
	1 pint corn	1	do	
	2 pints corn	1	do	
	1 pint wheat scourings	1	do	
	2 pints wheat scourings	1	do	
	1 pint wheat scourings	$1\frac{3}{4}$	do	
	2 pints wheat scourings	$1\frac{3}{4}$	do	
	2 pints floor sweepings	1	do	
	1 pint floor sweepings	1	do	
3.30				Shut down.
Summary:	12 attempts		No explosions	

Date: June 26, 1916.
Weather: Clear; warm; humidity, about 70 to 80 per cent.
Observers: B. W. Dedrick, R. B. Fehr, B. J. Culp, J. Weaver

TABLE 7.—*Series 7. Induction coil.*

Time.	Feed.	Length of spark.	Observations.	Remarks.
a. m.		*Inches.*		
8.15				Started mill. Spark gap located about 6 inches to one side of shaft.
8.30	2 pints corn	½	No explosion	
	1 pint flour	½	do	
	do	½	do	
	1 pint wheat scourings	½	do	
	do	½	do	
	1 pint fine floor sweepings	½	do	
	do	½	do	
8.50	1 pint 1:2 mixture elevator dust and oat hulls	½	do	
Summary:	8 attempts		No explosions	

Date: June 27, 1916.
Weather: Clear; temperature, 82° F.; humidity, 82 per cent.
Observers: B. W. Dedrick, R. B. Fehr, B. J. Culp, J. Weaver.

TABLE 8.—*Series 8. Revolving damper.*

Time.	Explosion No.	Feed.	Position of damper.	Observations.				Remarks.
				A.	B.	C.	E.	
a. m. 8.15								Started mill.
8.30–8.50								Ran Series 7. Temperature, 82° F.; humidity, 82 per cent.
8.50								Substituted carbons for brass balls. Continuous arc.
9.00	1	Flour	Off	2 puffs	Nothing	Puff	2 puffs	About 1 pint of feed each time.
	2	do	do	Big flash	do	do	Puff	
	3	do	do	do	do	do	do	
	4	do	do	Small flash	do	do	do	
	5	do	On	2 small flashes	do	Nothing	Nothing	
	6	do	do	Small flash	do	do	do	
	7	do	do	Very large flash	do	do	do	Damper stuck.
	8	do	do	2 large flashes	do	do	do	
9.40	9	do	do	do	do	do	do	
	10	do	Off	Large flash	do	Puff	Puff	
	11	1:1 mixture elevator dust and oat hulls.	do	do	do	do	do	
	12	do	On	do	do	Nothing	Nothing	
	13	1:3 mixture elevator dust and oat hulls.	Off	do	do	Puff	Puff	Largest so far in this series.
		do	On	Nothing				
		1:5 mixture elevator dust and oat hulls.	do	do				
	14	Wheat scourings	do	Large flash	**Flash**	Nothing	Nothing	Flame got past damper.
		do	Off	Nothing				3 pints feed.
	15	do	do	Small flash	Nothing	Puff	Nothing	2 pints feed
	16	do	do	Large flash	do	do	do	Do.
	17	do	On	do	do	Flash	do	Do.
	18	Flour	Off	do	do	Puff	do	Do.
	19	do	do	do	do	5 flashes	do	Do.
10.05	20	do	On	do	**Flash**	Nothing	do	Do.

								Hopper and floor on fire. Extinguished by "pyrene." Mill shut down. Temperature, 88° F.; humidity, 72 per cent.
p. m. 2.30								Mill started. Temperature, 86° F.; humidity, 87 per cent.
2.35	21	Flour	Off	Flash	Nothing	Flash	Puff	
	22	do	On	Small flash	do	Nothing	Nothing	Fire in hopper.
	23	do	do	Large flash	do	do	do	
2.50	24	do	Off	Flash	do	Puff	Puff	
2.52								Thunderstorm. Mill shut down.
Summary:		27 attempts		24 explosions (13 damper off, 11 damper on).	2 flashes (past damper).	2 flashes (damper off) 11 puffs (damper off).	9 puffs (damper off) No puffs (damper on).	

Date: June 27, 1916.
Observers: B. W. Dedrick, R. B. Fehr, B. J. Culp, F. Kline, J. Weaver.

TABLE 9.—*Series 9. Revolving damper.*

Time.	Explosion No.	Feed.	Position of damper.	Observations.				Remarks.
				A.	B.	C.	E.	
p. m. 2.10								Started mill. Humidity, .63 per cent. Electric arc.
2.30		Flour	Off	Nothing				6 attempts.
2.40	1	do	do	Puff				
	2	1:1 mixture wheat scourings and flour.	do	Big flash	Nothing	Flash	Nothing	
	3	do	do	2 flashes	do	do	do	
	4	do	On	do	do	Nothing	do	
	5	do	do	do	do	do	do	
	6	do	Off	3 flashes	do	3 flashes	Puff	
	7	do	On	2 big flashes	**Sparks**	Nothing	Nothing	
	8	do	do	1 big flash	**Large flash**	do	do	
	9	do	Off	4 flashes	Nothing	2 flames	Puff	
	10	do	do	Flash	do	Puff	do	
	11	do	do	do	do	Big flash	do	
	12	do	On	3 flashes	do	Nothing	Nothing	
	13	do	do	2 flashes	do	do	do	
	14	do	do	Flash	do	do	do	
	15	do	Off	do	do	Puff	Puff	
	16	do	do	do	do	Big flame	do	
	17	do	On	do	do	Nothing	Nothing	
3.10	18	do	do	do	**Flash**	do	do	
								Stopped to extinguish fire in hopper.
3.20	19	Wheat scourings	Off	Flash	Nothing	Flash	Puff	
		do	On	Nothing				4 attempts.
	20	do	Off	Flash	Nothing	3 flashes	Puff	
	21	Flour	On	2 flashes	**Flash**	Nothing	Nothing	
	..	Flour and scourings	Off	Nothing				2 attempts.
	22	do	do	2 flashes	Nothing	Nothing	Puff	
	23	do	On	Flash	do	do	Nothing	
	24	do	do	do				No observations at B, C, and E made.
	25	do	do	Small flash				Do.
	26	do	do	do				Do.
	27	Mixture from conveyor.	do	Large flash	Nothing	Nothing	Nothing	
	28	do	Off	2 small flashes	do	Puff	Puff	
	29	do	do	Flash	do	do	do	

	30	do	do	3 flashes	do	3 flashes	do	No observation at B.
	31	do	On	Large flash		Nothing	Nothing	
	32	do	do	do	Nothing	do	do	
		do	do	Nothing				
3.40	33	do	do	2 large flashes	Nothing	Nothing	Nothing	Mill shut down.
Summary:		46 attempts	15 off, 18 on (during explosion).	33 explosions	4 flashes (damper on)	9 flashes (damper off), 4 puffs (damper off).	12 puffs (damper off), no puffs (damper on).	

Date: June 28, 1916.
Weather: Clear; slight breeze; temperature, 87° F.; humidity, 55 per cent.
Observers: B. W. Dedrick, R. B. Fehr, B. J. Culp, F. Kline, J. Weaver.

TABLE 10.—*Series 10. Static electricity.*

General conditions.			Observations.			Remarks.
Time.	Temperature.	Humidity.	Open belt.	Crossed belt.	Frame of machine.	
p. m.	*° F.*	*Per ct.*				
3.00			Violent deflection of gold leaf when contact was made to comb of pins near belt. Deflection when bare end of lead is held near belt; greater the farther it is from iron pulley.		No deflection when lead is touched to frame.	Apparatus: 5-foot flexible leads with 3-inch bare ends of No. 14 copper wire and sensitive goldleaf electroscope.
3.20	42	54	Deflection, even when hand touches bar end of lead, although not so great.	Same as in case of open belt, but deflections not so great. No effect if hand touches bare end of lead.		Attrition mill runs at normal speed of 2,200 r. p. m.
Summary:						In no case was there enough static electricity to cause a spark to jump from the belt to the knuckle.

Date: March 15, 1917.
Observers: R. B. Fehr, C. A. Nickle.

TABLE 11.—*Series 11. Double damper.*

Time.	Explosion No.	Feed.	Position of damper.	Observations.					Humidity.		Remarks.
				Mill A.	Damper B.	By-pass C′.	Conveyor.		In.	Out.	
							D.	E.			
a. m.									*Per ct.*	*Per ct.*	
7.15											Started mill.
8.30									82		Temperature, 46° F.
8.35		Old oat hulls									Started feeding.
8.45		New oat hulls									Started feeding. Recirculated.
8.50											Turned on arc, 15 to 20 amperes.
9.00										83	
9.15–9.18											Arc off. Static electricity detected on belts by electroscope.
9.20											Temperature of feed at A, 82° F.
9.30									73		
9.46–9.50											Shut down to adjust idler.
9.50–9.55											Arc off.
10.00										76	
10.07–10.10											Fuse out. Shut down.
10.20–11.30											Shut down to align machine and tighten belts.
11.30									77	81	Started to rain. Test discontinued.
p. m.											
1.10										80	Mill started.
1.38	1	Flour	Off	Large flash	Puff	Puff	Puff	Puff			One quart feed. Electric arc.
1.41		do	On	Nothing							
1.44	2	do	do	Puff	Smoke	Nothing	Nothing	Nothing			Flour direct from store, 14.1 per cent moisture.
1.46		do	do	Nothing							
1.47		do	do	do							
1.48	3	do	do	Small puff	Nothing	Nothing	Nothing	Nothing			
1.49	4	do	do	2 puffs	Puff	Puff	Puff	Smoke			

1.51		do	do	Nothing						
1.52	5	do	do	Puff	Nothing	Nothing	Nothing	Nothing		
1.53	6	do	Off	do	Puff	Puff	Puff	Smoke		
1.55	7	do	do	2 puffs	2 puffs	Flash and puff	2 puffs	do		
1.57	8	do	do	Puff	Puff	Puff	Puff	do		
2.02		do	do	Nothing						83
2.03		do	do	do						
2.04		do	do	do						
2.12	9	do	On	4 puffs	**Long flame**	Flash	**Flash**	Smoke			Flour had been in drying oven, 9.3 per cent moisture.
2.18	10	do	do	Large flame	**Long flame**	do	**Flash**	Nothing		
2.24	11	do	Off	2 flashes	Puff	Smoke	Puff	Puff		
2.30		do	do	Nothing					61	
2.33–2.35		Conveyor	do	do							Three attempts. Ground products from conveyor.
2.38–2.40		Wheat scourings	do	do							Three attempts.
2.42–2.45		No. 2 feed dust	do	do							Five attempts.
2.49–2.52		No. 1 feed dust	do	do							Four attempts.
2.54–2.55		Fine oat hulls	do	do							Two attempts.
2.56		1:3 mixture elevator dust and oat hulls.	do	do					58	83	
3.00											Static electricity detected on belts of machine.
Summary.		37 attempts		11 explosions (5 with damper off, 6 with damper on).	2 flashes (damper on) 1 puff (damper on).	3 flashes (damper on) 4 puffs (damper on).	2 flashes (damper on) 1 puff (damper on).	2 smokes (damper on).			

Date: May 4, 1917.
Weather: Clear; slight breeze; temperature, 41° F.
Observers: B. W. Dedrick, R. B. Fehr, P. X. Rice, R. E. Campbell, V. C. George, J. Weaver, R. P. Lewis, J. A. Spanogle, J. O. Reed, A. Kerstetter.

TABLE 12.—*Series 12. Demonstration.*

Time.	Explosion No.	Feed.	Position of damper.	Observations.					Humidity.		Remarks.
				Mill A.	Damper B.	By-pass C′.	Conveyor.		In.	Out.	
							D.	E.			
									Per ct.	*Per ct.*	
a. m. 8.15											Temperature outside, 58° F.; humidity, 61 per cent.
8.25											Started mill.
8.40		Dried oat hulls									Started feeding. Arc on continuously. Recirculated.
9.15									44	60	
10.30									44	48	
11.15									44	48	
11.30	1	Fine dust (oat hulls) from conveyor.		Small flame							
11.34	2	do		do							
11.42											Nailed peepholes shut, thus jarring conveyor.
11.45	3			Small puff, followed by a 3-foot flame.							Probably due to dust stirred up by sweeping in vicinity of hopper.
p. m. 1.55		Fine oat hulls from morning's grinding.		Nothing							2 attempts.
2.00		Fine oat hulls from morning's grinding (1 quart).	Off	Large flash	Nothing	Flash	Puff	Smoke	46	49	
2.06		do	On	Nothing							9 attempts.
2.20											Collected everything in system.
2.26–2.27		Flour from series 11		Nothing							3 attempts. 14.1 per cent moisture.
2.30		Dry flour		do					49	48	3 attempts. 10.2 per cent moisture.
2.35	5	Mixture dry flour and No. 2 feed dust.	On	2 puffs	**Flash**	Nothing	Nothing	Nothing			
2.37	6	No. 3 elevator dust	do	Large flash	**Flash**	do	**Flash**	Smoke			
2.39		No. 1 feed dust	do	Nothing							

2.40	7	No. 2 feed dust	do	2 large flashes	**Flash**	Nothing	**Flash**	Smoke and burned particles.			
2.41	8	No. 2 feed dust (2 quarts).	do	2 flashes	**Flash**	do	**Flash**	do			
2.48	9	No. 3 elevator dust	Off	Small flash	Nothing	Small puff	Nothing	Smoke			
2.50	10	do	do	do	do	do	do	do			
2.51	11	do	do	do	do	do	do	do			
2.52	12	Mixture No. 3 elevator dust and dry flour.	do	5 flashes	do	Large puff	Puff	do			Fire in A. Mill shut down.
4.00									45	48	Mill started again. Induction coil with $\frac{1}{2}$-inch spark used.
4.12		Same as No. 12		Nothing		Large puff					Used induction coil. 5 attempts.
4.20		do		do							Small pieces of flint. 4 attempts.
4.22		No. 3 elevator dust		do		Large puff					Small pieces of flint. 6 attempts.
Summary.		30 attempts		12 explosions (4 with damper on).	4 flashes (damper on).		3 flashes (damper on).	3 smokes (damper on).			

Date: May 16, 1917.
Weather: Mild and clear; temperature, 70° F.
Observers: S. Soars, L. C. Winegardner, J. H. Heishman, G. J. Noth, J. P. Van Gelder, R. L. Sackett, B. W. Dedrick, R. B. Fehr, P. X. Rice, R. E. Campbell.

TABLE 13.—*Series 13. Effect of relief valve.*

Time.	Explosion No.	Feed.	Observations.				Remarks.
			Mill A.	Damper B.	Relief G.	Conveyor E.	
a. m.							
7.30							Started mill; damper on.
8.30							Temperature outside, 64° F. Humidity, 84 per cent. Electric arc.
8.40		Oat hulls	Nothing				3 attempts.
8.47	1	1 pint flour and 1 pint No. 3 elevator dust, unmixed.	3 flashes	Smoke	Flame and 2 puffs	Smoke	
8.50	2	do	2 flashes	**5-foot flame**	3-foot flame and 1 puff	do	Relief not effective.
8.58		1 : 2 mixture flour and No. 3 elevator dust.	Nothing				
9.00		No. 3 elevator dust	do				
9.02		1 : 1 mixture flour and No. 3 elevator dust.	do				
9.03		do	do				
9.05	3	1 pint flour and 1 pint No. 3 elevator dust, unmixed.	2 flashes	Smoke	Smoke		
9.07		No. 2 feed dust	Nothing				
9.08		1 : 1 mixture flour and No. 2 feed dust	do				
9.10	4	1 : 1 mixture flour and No. 3 elevator dust.	3 flashes	**3-foot flame**			No observations.
9.23	5	do	2 flashes	**1-foot flame**	2 puffs		Conveyor, 158 r. p. m.
9.25	6	do	Flash	Smoke	Smoke		Damper, 135 r. p. m.
9.26	7	do	3 flashes	**Small flame**	3 puffs		
9.28	8	do	2 large flashes	Nothing	2 flames (4-foot)		Humidity, inside and outside, 72 per cent.
10.34	9	do	Explosion		Flames and puffs		
10.35	10	do	do		do		
10.36	11	do	do		do		
10.39	12	do	2 explosions		do		
10.47	13	1 : 1 mixture flour and No. 2 feed dust	Explosion		do		
10.48		do	Nothing				
10.49	14	do	Explosion		Flames and puffs		
Summary.		24 attempts	14 explosions	4 flames	3 flames (first 8 explosions).	No puffs	

Date: June 9, 1917.
Weather: Clear; mild; temperature, 64-77° F.
Observers: R. L. Sackett, B. W. Dedrick, R. B. Fehr, P. X. Rice, R. E. Campbell, J. Weaver.

TABLE 14.—*Series 14. Various cereal dusts.*

Time.	Explosion No.	Feed.	Observations.					Humidity.		Remarks.
			Mill A.	Damper B.	Relief G.	By-pass C′.	Conveyor E.	In.	Out.	
a. m.								*Per ct.*	*Per ct.*	
9.00										Started mill; damper on.
11.05		Barley malt sprouts							80	No explosions with arc.
11.35		do						68		Do.
12.00										Stopped feeding.
p. m.										
1.20		Malt sprouts	Nothing							Arc on continuously.
2.00			do						66	Closed all holes, to keep in dust while grinding with arc on. No explosion.
2.40	1	Malt sprouts (unground)	Small puff	Nothing	Puff					Large scoopfuls hereafter (2 to 4 quarts).
	2	Malt sprouts (ground)	do	do	do					
	3	do	do	do	do					
	4	do	do	do	do					
	5	do	do	do	do					
	6	do	do	do	do					
2.46		do	Nothing							
2.47	7	Malt sprouts	Small puff	Nothing	Small puff					Collected after explosions in 1–6.
	8	do	do	do	do					Do.
	9	do	do	do	do					Do.
2.50	10	1:1 mixture malt sprouts and No. 3 elevator dust.	Large puff	do	do					
	11	do	Small puff	do	do					
	12	do	do	do	do					
2.55	13	1:1 mixture malt sprouts and barley malt sprouts.	Puff	do	do					
	14	do	do	do	do					
	15	do	do	do	do					
		do	Nothing							
	16	do	Puff	Nothing	Small puff					
		do	Nothing							
.10	17	do	Puff	(Off)	Small puff	Puff				
	18	do	do	do	do	do				
	19	do	do	do	do	do				
	20	do	do	do	do	do				
	21	do	do	do	do	do				
	22	do	do	do	do	do				
		do	Nothing	do						

TABLE 14.—*Series 14. Various cereal dusts*—Continued.

Time.	Explosion No.	Feed.	Observations.					Humidity.		Remarks.
			Mill A.	Damper B.	Relief G.	By-pass C′.	Conveyor E.	In.	Out.	
p. m. 3.20	23–27	Brewers' dried grains	5 explosions	(On) Nothing.	5 puffs					No explosion when being recirculated. Not much smoke, except when fed by the scoopful. 8 attempts.
3.45		1:3 mixture conveyor product and brewers' dried grains.						66		
	28–31	do	4 puffs	Nothing	4 small puffs					4 attempts.
4.35	32–36	Oat hulls containing much dust.	5 puffs	do	5 puffs					8 attempts. No flames. No explosion when being recirculated, only when fed several quarts at a time.
5.00	37–38	Barley malt sprouts	2 puffs	do	2 small puffs				68	10 attempts. Much smoke.
5.20										Shut down.
Summary.		59 attempts	38 explosions (32 with damper on).	(On) Nothing.	38 puffs		(Damper on) Nothing.			

Date: September 11, 1917.
Weather: Clear; no wind; temperature, 50-60° F.
Observers: B. W. Dedrick, R. E. Campbell, A. Kerstetter.

TABLE 15.—*Series 15. Various cereal dusts.*

Time.	Explosion No.	Feed.	Observations.					Humidity.		Remarks.
			Mill A.	Damper B.	Relief G.	Conveyor—		In.	Out.	
						D.	E.			
p. m.								*Per ct.*	*Per ct.*	
12.00										Started mill. Damper in service.
1.55		Malt sprouts						52		Started feeding.
2.02		1 quart malt sprouts and about 2 dozen matches.	Nothing							2 attempts.
2.10										Electric arc turned on.
2.15		1 quart malt sprouts	Nothing							
		do	do							
	1	2 quarts malt sprouts	Flash	Puff	4-foot puff	Nothing	Nothing			
2.19		1½ quarts malt sprouts	Nothing							
2.20		do	do							
2.21	2	2 quarts malt sprouts	Flash	Puff	3-foot puff	Nothing	Nothing			
2.24	3	do	do	do	do	do	do			
2.26		do	Nothing							
2.27	4	do	Flame	Puff	3-foot puff	Nothing	Nothing			
2.29	5	3 quarts malt sprouts	do	do	do	do	do			
2.30	6	4 quarts malt sprouts	do	do	do	do	do	56		
2.34		1 quart malt sprouts (finely ground).	Nothing							
2.35		do	do							
2.36	7	2 quarts malt sprouts (finely ground).	Flash	Puff	3-foot puff	Nothing	Nothing			
2.37	8	1 quart floor sweepings	do	do	Flash and puff	do	do			
2.38										Arc off.
2.39		2 quarts finely ground malt sprouts with nails, matches, and flint.	Nothing							No explosion.
2.42		do	do							Do.
3.00		½ bushel "dried grain"						55	62	Recirculated.
3.14		1 quart "dried grain"	Nothing							Arc on.
3.18		do	do							
3.19		2 quarts "dried grain"	do							
3.20		do	do							
3.21		3 quarts "dried grain"	do							
3.22		do	do							
3.26		1 quart 1 : 1 mixture flour and "dried grain."	do							
3.28	9	1 quart dry flour	2 flashes	**7-foot flame.**	Flame and puff.	Flash	Flame and sparks.			
3.30	10	do	do	**3-foot flame.**	2 flames (2-foot).	Flame	Nothing			
3.34		1 quart 1 : 1 mixture "dried grain" and flour.	Nothing							

TABLE 15.—*Series 15. Various cereal dusts*—Continued.

Time.	Explosion No.	Feed.	Observations.					Humidity.		Remarks.
			Mill A.	Damper B.	Relief G.	Conveyor— D.	Conveyor— E.	In.	Out.	
p. m.								*Per ct.*	*Per ct.*	
3.36		1 quart 1 : 2 mixture "dried grain" and flour.	Nothing							No explosion.
3.37	11	do	2 small puffs	**Large flash**	2 puffs (3-foot)	Flash	Burned particles.			
3.38										Arc off.
3.40		1 quart flour with matches, nails, and flint.	Nothing							No explosion.
3.45								56	60	Arc on. No recirculation.
3.58		1 quart oat hulls	Nothing							
4.00		2 quarts oat hulls	do							
4.01		3 quarts oat hulls	do							
4.03		1 quart barley malt sprouts	do							
4.04		2 quarts barley malt sprouts	do							
4.06		3 quarts barley malt sprouts	do							
4.07		1 quart brewers' dried grain	do							
4.08		2 quarts brewers' dried grain	do							
4.09		3 quarts brewers' dried grain	do							
4.13		2 quarts 1 : 1 mixture oat hulls and flour.	do							
4.14		2 quarts 1 : 1 mixture barley malt sprouts and flour.	do							
4.16	12	2 quarts 1 : 1 mixture brewers' dried grain and flour.	Puff	Small puff	3-foot puff	Nothing	Nothing			
4.18		1 quart conveyor mixture	Nothing							
4.19		2 quarts conveyor mixture	do							
4.20		3 quarts conveyor mixture	do							
4.21		1 quart 1 : 1 mixture conveyor mixture and flour.	do							
4.23	13	2½ quarts 1 : 1 mixture conveyor mixture and flour.	5 puffs	**3-foot flame**	5 puffs	Nothing	Nothing			
4.27								55	70	Mill shut down.
Summary.		43 attempts	13 explosions (damper on).	4 flames (damper on) 9 puffs (damper on).	3 flames, 10 puffs	3 flashes (damper on) no puffs.	1 flame (damper on).			

Date: October 3, 1917.
Weather: Clear; no breeze; temperature, 67-64° F.
Observers: R. L. Sackett, B. W. Dedrick, R. B. Fehr, R. E. Campbell, H. R. Brown, J. Weaver, A. Kerstetter.

DISCUSSION OF RESULTS AND CONCLUSIONS.

SPARKS EMITTED BY FOREIGN SUBSTANCES.

Many attempts were made, in both the preliminary and the regular tests, to produce dust explosions in an attrition mill by introducing with the feed various kinds of foreign substances, such as nails, small pieces of stone and flint, and matches, but not once did an explosion occur. Various kinds of grain products, with different degrees of fineness, and both normal and minimum moisture contents, were fed during these attempts. Evidently, however, the intensity and amount of the heat generated by the sparks from these foreign substances were not sufficient to ignite the dust, although an explosive mixture of air and dust may have been present, as manifested by the regularity of the explosions obtained by the electric arc under identical conditions. In rare cases, and especially with very low humidity and moisture contents, it might be possible for a nail or other hard substance to be caught in such a way that a very long succession of sparks would be emitted with sufficient intensity to cause ignition. The results of these tests, however, point strongly to the following conclusions:

1. Sparks emitted by foreign substances passing through an attrition mill do not in general appear to be hot enough to ignite an inflammable dust.

2. Nevertheless, to take care of the exceptional case, every precaution should be taken to keep all foreign substances from entering the grinding machines.

NAKED FLAME.

Only two attempts were made to obtain explosions by means of a naked or open flame, but both were entirely successful (p. 11). Safe conclusions are as follows:

1. Naked flames can readily ignite inflammable dust mixtures.
2. A naked flame should never be allowed in the vicinity of dust.

CARBON ARC IN ATTRITION MILL.

The summary of all results obtained with the use of the electric arc is shown in Table 16. It is to be noted that in practically two-thirds of the attempts with materials which gave explosions at one time or another, explosions were obtained by means of an electric arc located near the grinding discs. In every one of the 201 explosions, except Explosion 3 of Series 12, it was necessary to feed the material in the amount of at least a handful to produce an explosion. Apparently, a fairly dense cloud of dust was required to produce an explosion with even the most intense source of ignition available, the electric arc. The following conclusions can be drawn:

1. An attrition mill is capable of producing mixtures of dust and air which can be easily ignited by a sufficiently intense source of heat.

2. There is much less danger of an explosion, when the rate of feeding is less than the amount which the mill can take care of.

TABLE 16.—*Summary of explosions in attrition mill (electric arc and foreign substances).*[1]

Mixture No.	Variety designation.	Material.	Series.										Attempts with foreign substances.	Total.
			1	2	3	8	9	11	12	13	14	15		
1	A	Fine oat hulls	0/2					0/2	1/12		5/8	0/3	1	6/27
2	B	Elevator dust	2/2	4/5	3/4								1	9/11
3		Mixture of fine oat hulls and elevator dust	1/1											1/1
4		1:3 mixture of oat hulls and sweepings, and elevator dust.	1/1											1/1
5		1:1 mixture of elevator dust and oat hulls		1/1		2/2								3/3
6		1:2 mixture of elevator dust and oat hulls		2/2	1/1									3/3
7		1:3 mixture of elevator dust and oat hulls		2/2		1/2		0/1						3/5
8		1:4 mixture of elevator dust and oat hulls		3/3										3/3
9		1:5 mixture of elevator dust and oat hulls		1/1		0/1								1/2
10		1:7 mixture of elevator dust and oat hulls		2/2	1/1									3/3
11		1:9 mixture of elevator dust and oat hulls		0/3										0/3
12		Conveyor mixture and oat hulls		1/1										1/1
13	C	Oat hulls		0/1						0/3				0/4
14	D	Flour (8 to 14 per cent moisture)			5/6	17/17	2/8	11/19	0/6			2/2	1	37/58
15	E	Graham flour			1/1									1/1
16		1:1 mixture of flour and elevator dust			1/1									1/1
17	F	Wheat scourings			2/2	4/5	2/6	0/3						8/16
18	G	Corn			4/4								2	4/4
19		1:1 mixture of corn and elevator dust			4/4								2	4/4
20		1:2 mixture of corn and elevator dust			1/1									1/1
21		Flour, corn, and elevator dust			1/1									1/1
22	H	Wheat shorts			0/1									0/1
23		1:2 corn and flour			1/1									1/1
24	I	Coarse floor sweepings			3/3							1/1		4/4
25	J	Fine floor sweepings			4/4									4/4
26	K	Conveyor mixture			4/4		7/8	0/3				0/3		11/18
27		1:1 mixture of wheat scourings and flour					22/24							22/24
28	L	No. 2 feed dust						0/5	2/2	0/1				2/8
29	M	No. 1 feed dust						0/4	0/1					0/5
30	N	Fine oat hull dust							3/3					3/3
31		Mixture of dry flour and No. 2 feed dust							1/1					1/1
32	O	No. 3 elevator dust							4/4	0/1			6	4/5
33		Mixture of dry flour and No. 3 elevator dust							1/1				4	1/1
34		1:1 mixture of flour and No. 3 elevator dust								12/14				12/14
35		1:2 mixture of flour and No. 3 elevator dust								0/1				0/1
36		1:1 mixture of flour and No. 2 feed dust								2/4				2/4
37	P	Barley malt sprouts									2/12	0/3		2/15
38	Q	Malt sprouts									9/11	7/13	4	16/24
39		1:1 mixture of malt sprouts and No. 3 elevator dust									3/3			3/3
40		1:1 mixture of malt sprouts and barley malt sprouts									10/13			10/13

42	....	1:3 mixture of conveyor product and brewers' dried grain	....	....	....	....	....	....	....	....	4/4	....	....	4/4
43	S......	Dried grain	....	....	....	....	....	....	....	....	....	0/6	....	0/6
44	....	1:1 mixture of dried grain and flour	....	....	....	....	....	....	....	....	....	0/2	....	0/2
45	....	1:2 mixture of dried grain and flour	....	....	....	....	....	....	....	....	....	1/2	....	1/2
46	....	1:1 mixture of oat hulls and flour	....	....	....	....	....	....	....	....	....	0/1	....	0/1
47	....	1:1 mixture of barley malt sprouts and flour	....	....	....	....	....	....	....	....	....	0/1	....	0/1
48	....	1:1 mixture of brewers' dried grain and flour	....	....	....	....	....	....	....	....	....	1/1	....	1/1
49	....	1:1 mixture of conveyor mixture and flour	....	....	....	....	....	....	....	....	....	1/2	....	1/2
		Total	4/6	16/21	36/39	24/27	33/46	11/37	12/30	14/24	38/59	13/43	21	201/332

Number of attempts with materials that gave explosions at one time or another, 305.
Maximum temperature, 87° F.; minimum temperature, 41° F.; maximum humidity, 97 per cent; minimum humidity, 44 per cent.

[1] Each variety of material tested is given a letter (p. 10), while each different mixture and variety of material is given a number (1 to 49) for ready reference. The denominator of a fraction indicates the number of attempts to obtain explosions, and the numerator indicates the number of successful attempts—i. e., explosions obtained with a particular material in a given test. An expression like "1:3 mixture of elevator dust and oat hulls" means that there is 1 part (by volume) of elevator dust to 3 parts of oat hulls.

CARBON ARC IN DUST ROOM.

The location of the arc in the dust room, at the end of the screw conveyor, did not cause an explosion (Series 4). This fact, however, merely indicates that the many conditions involved in an explosive mixture did not happen to be met in this particular case. Probably the dust cloud was not dense enough. In any event, it would be well to draw the following conclusion, especially in view of past explosions in mills, and those obtained by the arc located near the grinding discs of the attrition mill:

It is always very dangerous to allow an open flame (or any source of ignition) in the vicinity of a dust-laden atmosphere.

EXPLOSIBILITY OF VARIOUS GRAINS.

The summary of all the explosions of various materials obtained with the electric arc (except those in the demonstrations, Series 5) is found in Table 16. From the explanation of the meanings of the terms of the fractions appearing in this table it would seem that each fraction ought to indicate the inflammability of the material. As a matter of fact, these fractions, especially those of the same series, serve as rough indications of the relative inflammabilities of the various materials; but too much stress should not be laid upon this point, as most of the conditions of testing were beyond control. Relative inflammability can properly be determined only by careful laboratory methods which control the many factors entering into the question.

In view of the fact that the grinding of oat hulls constitutes an important part of the work done by attrition mills, it is interesting to note that oat hulls alone (Mixtures 1, 13, and 30) were not found to be very inflammable. Only extremely fine oat hulls, or those with considerable dust, were capable of giving inflammable mixtures, in spite of the fact that in series like 11 and 12 oat hulls were fed into the mill and recirculated continuously for several hours without a resulting explosion, except in the case of Explosion 3 of Series 12.

A study of Table 16, together with a knowledge of the conditions of testing, makes possible the following conclusions:

1. Elevator dust, flour, wheat scourings, and malt sprouts seem to produce explosions the most consistently.

2. Oat hulls do not appear to give very inflammable mixtures, unless they contain a considerable amount of fine dust.

3. Every precaution should be taken to remove dust as fast as it is formed, and to prevent it from coming in contact with any possible source of ignition.

STATIC ELECTRICITY IN ATTRITION MILLS.

Repeated tests were made on various days, June 22, 23, 26, and July 1, 1916, to detect any charges of static electricity that might have been built up during the operation of the attrition mill. The devices employed for transferring the charge to the electroscope included the copper wire described in Series 10 (p. 16), and also a proof plane, consisting of a penny attached by sealing wax to a ¼-inch glass tube 10 inches long. The copper lead and proof plane each gave good deflections of the electroscope when these devices were applied to bodies known to have charges of static electricity, and therefore it was certain that the methods employed for indicating the presence of static electricity were reliable. In the tests involving the use of the proof plane, it was held near the moving belt, or brought in contact with the frame of the machine, and then touched to the binding post of the electroscope, which was grounded by holding in the hand.

None of the tests run on the summer days mentioned, in none of which the humidity was lower than 70 per cent, indicated the slightest trace of static electricity during the operation of the attrition mill, with and without the feeding of various grains. This result indicated either that no static charge was being generated or the machine was too well grounded, either directly or by leakage, to retain any charge that might have been generated.

By means of the usual voltmeter method the metal frame of the attrition mill was found to be well insulated as far as low voltages (110) were concerned.

In order to test qualitatively the insulation and leakage for high voltages, one terminal of a Wimshurst machine was connected to the frame of the attrition mill. By means of the proof plane and electroscope it was found that the attrition mill was capable of retaining a slight charge for a few seconds after the charging wire had been removed. The indications of the very sensitive electroscope, however, were so feeble as to lead to the conclusion that, while the attrition mill was fairly well insulated, its leakage (owing to the many corners and edges, covering of dust, and also atmospheric moisture) and its capacity were so great that a considerable quantity of electricity would be required to establish a high potential on the frame.

Further tests (Series 10) on a winter day (temperature 42° and humidity 54 per cent) indicated the development of static electricity in the driving belts, due probably to the comparatively low moisture content of the air, but not in the frame of the machine.

Safe conclusions from these tests are as follows:

1. Any static electricity that may be generated in this particular machine is dissipated so rapidly by leakage, which is largely due to

the relatively high atmospheric humidity of this region, that no potential is built up in the frame of the machine.

2. Should an excessive amount of static electricity be developed in a mill of any kind, proper methods of grounding the machine[1] will go far toward eliminating any danger that may be due to sparks from static charges.

STATIC ELECTRICITY AS CAUSE OF EXPLOSIONS.

In 25 attempts to ignite inflammable dusts with the spark from an induction coil, not a single explosion was obtained (Series 6, 7, and 12). From the fact that an electric arc would produce explosions under identical conditions, it would seem that the production of an explosion is largely dependent upon the extent as well as the intensity of the source of ignition, especially when there is a high velocity of the dust past the igniter, as is the case in the attrition mill. The temperature of the electric arc is estimated at about 6,200° F., but laboratory experiments[2] have shown that certain dusts can be ignited at as low a temperature as 1,100° F. with a source of heat having a comparatively small area. Consequently, great care should be exercised to eliminate every possible source of ignition.

Conclusions:

1. It is comparatively difficult to ignite inflammable dusts in an attrition mill by means of static electricity.

2. Nevertheless, every precaution should be taken to eliminate static electricity in the operation of any kind of mill.

EFFECT OF ATMOSPHERIC HUMIDITY.

The effect of humidity, both relative and absolute, upon the inflammability of dusts is not yet known, and can not be definitely determined except by laboratory investigations under carefully controlled conditions. In the tests in the attrition mill the humidity of the atmosphere was always determined by means of a carefully calibrated sling psychrometer. The relative humidity ranged from 44 per cent to very nearly saturation, or 100 per cent, in the case of a steady rain. No deductions could be made as to the effect of the relative humidity on the inflammability of grain dusts, for too many variable factors were involved. It is, however, of interest to note that in Series 3, during a steady rain, the regularity of explosions happened to be greater than in any other series. This fact seems to indicate, at least, that a high relative humidity does not tend to decrease the inflammability of dusts, except in so far as the moisture content of the materials fed into the mill may be considerably increased after a sufficient length of time.

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[1] References 38 and 39, Bibliography.

[2] Reference 26, Bibliography.

Conclusions: There is no positive indication in the present series of tests that the humidity of the atmosphere has any material effect on the inflammability of dusts in this region, where the relative humidity is usually above 50 per cent.

TABLE 17.—*Moisture contents of materials.*

Designation.	Material.	Series.				
		5[1]	11	12	14	15
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
A	Fine oat hulls	9.6	9.9	5.7		
B	Elevator dust	9.8				
C	Oat hulls	8.9		3.2	9.2	3.3
D_1	Flour (direct from store)		14.1			
D_2	Flour (oven dried)		9.3	10.2		8.5
F	Wheat scourings	10.4	9.0	5.7		
G	Corn	9.9				
I	Coarse floor sweepings	8.6				
K	Conveyor mixture	9.0				
N	Fine oat hull dust			5.2		
P	Barley malt sprouts				9.4	4.0
Q	Malt sprouts				12.0	3.5
R	Brewers' dried grain				9.4	4.7

[1] Also typical of the first 9 series.

EFFECT OF MOISTURE CONTENT OF MATERIALS.

Table 17 gives the results of moisture determinations made in several tests. Average samples were obtained during the feeding of the materials into the attrition mill, and were kept in carefully stoppered bottles. The method for making the moisture determinations was similar to that employed for coal analysis, in which the samples are placed in a constant temperature oven at 220° F. The crucibles containing the samples were weighed, by means of analytical balances, at frequent intervals of time until the material was dried out, as indicated by two successive weights of practically the same value. The percentage of moisture was then calculated on the basis of the original wet sample. Duplicate determinations were made in each case.

The number of moisture determinations and the range of moisture contents were not sufficient to enable one to draw any positive conclusions, but, in the case of oven-dried flour at least, a tendency toward more regularity and violence of explosions was noted. Undoubtedly the same tendency would be noted in all grains if the conditions of testing could be properly controlled, and it would perhaps be advisable to determine the minimum amount of moisture to render the material noninflammable. For the present it seems that the following conclusions may safely be drawn:

1. The less moisture a dust contains, the more inflammable it is likely to be.

2. It is probable that for inflammable dusts there is a maximum moisture content above which the dusts can not be ignited.

TESTS OF REVOLVING DAMPERS OR FIRE TRAPS.

The tests with the revolving dampers gave the following important results:

TABLE 18.—*Tests of revolving dampers or fire traps.*

Observations.	Single damper.	Double damper.	Observations.	Single damper.	Double damper.
Explosions with dampers in service	29	69	Flashes at D		8
Flashes past damper	6	14	Puffs at D		1
Puffs past damper	0	10	Flashes at E	0	1
			Puffs at E	0	0

These results indicate that the double damper showed no superiority over the single damper as a preventive of flame propagation. With both single and double dampers there were cases in which flames got past with enough force to shoot out of the peephole (B) for several feet toward the observer. The devices, however, were effective to the extent that no puffs of smoke and only one flame were observed at the end (E) of the conveyor.

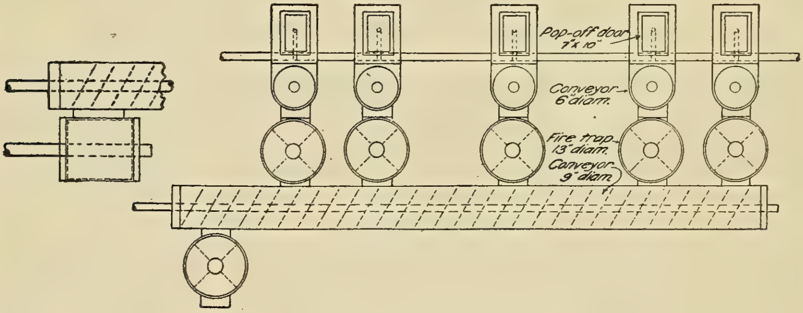

FIG. 5.—Attrition mills, showing fire traps or dampers.

An interesting practical application of the revolving damper as a "fire trap" is noted in the following report of an investigation by R. L. Sackett:

> A large milling company in Buffalo, N. Y., has placed its battery of attrition mills in a separate building of corrugated iron (fig. 5).
>
> Before the oats pass to the mill they have been screened and have passed a magnetic separator, which removes splinters of wood, metallic substances, and other foreign matter.
>
> The material passes through the attrition mills and drops down toward the conveyor below.
>
> The vertical leg below the mill has a 6-inch galvanized spout running horizontally through the side of the mill. On the end of this pipe is a flap valve with a circuit so arranged that if an explosion takes place in the mill the pressure will open the flap valve, break the electric circuit, which will in turn stop the motor which drives the mills. The pipe serves as a safety valve for the escape of gases in case of explosion.
>
> Below the safety valve is a "fire trap" or "damper," consisting of four blades revolving on a shaft, within a casing, so designed that in case of an explosion the propagation of flame to the conveyor will be retarded or prevented. This damper

is similar to those used in experiments in the special mill built at The Pennsylvania State College for the purpose of this investigation.

This company reports that no damage has been done, and, so far as they know, explosions have not been transmitted beyond the safety pipe and damper.

The double damper as installed in the present series of tests did not give the desired effect, probably because the two sets of revolving paddles were too close together. If the flame can pass one set of blades, it is likely that it can pass an adjacent set of blades before it has been extinguished. It seems reasonable to suppose, however, that a sufficient volume or extent of passage between the two revolving dampers may cause the flame to expend its energy to such an extent that the second damper would be able to check it absolutely.

The following conclusions can be drawn:

1. A single revolving damper is a fairly effective device for preventing the violent propagation of flames, but is by no means an absolute preventive.
2. A double revolving damper does not appear to serve the purpose of a fire trap any better than a single damper.

RELIEF VALVE AND PIPE.

Although the three tests with the relief valve and pipe leading from the hopper of the attrition mill to the outside of the building showed that this device was not effective in preventing the propagation of flames, even past the double revolving damper, it is quite possible that a larger size of valve and pipe may aid materially in accomplishing the desired result. The principle of permitting the immediate escape of confined gases that have just been ignited seems to be a proper one on which to base a preventive device.

Conclusions:

1. The relief valve and pipe as installed alone are not successful in preventing flame propagation.
2. In view of the correct principle involved, it may be worth while to try changes in the design and location of the relief valve and pipe.

A study of the foregoing discussion of the tests performed at the experimental plant of the college may lead to the objection that not enough attention was paid to the quantitative side of the problem, involving such factors as the exact amount of grain fed into the mill, the rate of feeding, the physical and chemical analyses of the material, the minimum temperature and minimum amount of heat to produce ignition, the velocity and analysis of the dust-laden gases at various points between the attrition mill and the end of the conveyor, the pressure developed by the explosion, the minimum humidity and the minimum amount of inert gases to prevent ignition of inflammable dusts, and the limits of inflammability for various dusts. To such a criticism the authors would reply that the quantitative side of the problem could be taken care of only by careful laboratory investigations such as are being conducted by the Bureau of Mines and the Bureau of Chemistry. The chief purposes of an experimental mill, such as that installed at the college, are to show that explosions can be produced in the grinding mill and propagated a considerable distance, and to test various preventive devices recommended by manufacturing concerns or by the Government. Both of these purposes have been served to some extent.

Although it has not been demonstrated that static electricity, or sparks emitted from foreign substances, are capable of producing explosions in an attrition mill, it has been positively proved that more intense sources of ignition, such as an open flame or electric arc, can easily ignite dust mixtures, and that the resulting explosion can be propagated through fire traps and the screw conveyor. Consequently, the safest plan is to guard against every possible source of ignition.

As to the second use, only three preventive devices have thus far been tested—a single revolving damper, a double revolving damper, and a relief valve. It would seem, however, that the present equipment would warrant further tests of preventive measures in cooperation with the Government.

SUMMARY OF CONCLUSIONS.

The final conclusions reached after studying grain-dust explosions in an experimental attrition mill, together with the other results obtained by Government investigators, may be summarized as follows:

1. Every effort should be made to collect and remove the dust from the grinding mill and surrounding atmosphere.
2. In some cases it may be advantageous to use inert gases to decrease the oxygen content and thus prevent the formation of an explosive mixture of air and dust.
3. Every possible source of heat should be eliminated where there is any danger of having a dust-laden atmosphere.
4. Every precaution should be taken to eliminate sparks due to static electricity.[1]
5. Greater use should be made of sheet iron on account of the very great danger from smoldering lumps of grain (Series 12, p. 17).
6. Revolving dampers, as installed here and elsewhere, appear to be of some value as preventive measures for the propagation of explosions.
7. The principle of the automatic relief valve should receive more attention as a possible remedy to apply for the partial prevention of the propagation of the flame.

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[1] References 38 and 39, Bibliography.

APPENDIX.

RECOMMENDATIONS FOR FUTURE INVESTIGATIONS.

In closing, the authors desire to offer the following recommendations for future investigations:

I. Laboratory experiments to determine the limits of inflammability as affected by the following factors:

1. Density of the dust cloud.
2. Fineness of the dust particles.
3. Chemical composition of the dust.
4. Moisture content.
5. Inert gases.
6. Atmospheric humidity.
7. Minimum temperature and amount of heat required for ignition.
8. Sparks from metallic substances.
9. Static electricity (not merely the voltage, but current measurements as well.)

II. Field experiments on various types of machines handling dusty materials:

1. Tests to prove that dust mixtures outside the limits of inflammability, as already determined, with reference to moisture content, inert gases, or atmospheric humidity, can not be ignited under the most severe conditions of ignition, such as those produced by an electric arc.
2. Tests of various devices designed to prevent the propagation of explosions.

RÉSUMÉ OF SOME PAST EXPLOSIONS.

The first large grain-dust explosion occurred in 1878 in the Washburn mill, at Minneapolis, Minn. At that time the "new process" system of milling, in which the grinding of wheat was done by millstones, was in vogue. It was assumed that, owing to a choking up of the feed spouts leading to the millstones above, one or more of the millstones became empty, and the running of the two stones against each other caused sparks, which ignited the dust in the conveyor boxes and dust rooms, causing an explosion in the dust room which destroyed the walls of the building. It is possible, and even probable, that the fire originated from open lights which were used at that time.

Another very serious mill explosion occurred on June 24, 1913, when a feed-grinding plant in Buffalo, N. Y., was completely wrecked by an explosion, presumably of dust. None of the survivors of this explosion was able to give any information as to the cause of the initial fire, but it is stated that without a doubt the explosion was caused by the ignition of feed dust.

A rather curious explosion took place in a flour mill in Nebraska on September 22, 1914, in which the entire wall on one side above the second story was blown out. One end showed a bad bulge, but the roof remained intact, except that it sagged over the side from which the wall was blown out. Apparently the force of the explosion was exerted in one direction, or, rather, the wall on this side offered less resistance than the others. It is believed that the dust in one of the flour bins was ignited by a match struck by one of the workmen.

On December 11, 1916, a large cereal mill in Ontario, Canada, was totally destroyed by an explosion and subsequent fire. The fire was started by an explosion in the feed-grinding building, and was ascribed to the ignition of feed dust in one of the grinding machines.

One of the authors witnessed several dust explosions in flour mills. Although these explosions were of minor importance, because no serious consequences followed, the observations tend to give an idea as to the explosibility of flour dust, the conditions under which explosions may take place, and, in some cases, the cause of the initial explosion.

At a certain mill the settlings of the dust room, into which was blown the dust drawn from the middlings purifiers and from the exhaust off the millstones, were gathered periodically into a bin and ground on a small stone. This mixture was composed of very fine pieces of bran, fiber, larger pieces of endosperm, and a fine, impalpable, starchy, flour dust. Often, when the spout became nearly empty and the pile above started down, the dust descended with sufficient force to spurt out of the opening in the spout over the hopper, creating a dense cloud of dust. On one occasion an open light was close at hand when this dust fell, and an explosion followed. There were three distinct explosions or flashes of the burning dust, one following the other at intervals of a few seconds. These explosions were succeeded by a faint crackling sound. Each successive flash was wider in extent as the dust spread and diffused.

The first enveloped only the vicinity of the spouts and millstone; the second, a still larger area; and the third, almost the entire area of the grinding floor. The first zone, composed of the heaviest and largest dust particles, burned the most slowly, as if partially smothered; the next, more rapidly; and the last and largest zone, composed of the very lightest of the starchy particles in the state of greatest diffusion, burned most rapidly, and, consequently, with the greatest heat. This last explosion had more force than the others, and was more of the nature of an explosion than the other two.

On another occasion some purified middlings were shaken down from the side of an empty bin, and, coming in contact with the flame of an open lamp, burned with two distinct flashes, the second one spreading somewhat beyond the confines of the bin. These middling particles were too heavy to float far, and too large to burn rapidly.

Only a few years ago a certain packer lifted the lid of a flour bin, and held a lighted match within the opening to see how much flour the bin contained. Apparently the flour had been drawn down partially, leaving some piled up on one side. Set in motion by a slight jar, it fell, causing a rush of air and a thick cloud of dust, which was followed immediately by a long flame issuing from the opening in the bin. The current of air caused by the fall of the flour was evidently strong enough to prevent the flame from extending down into the bin; otherwise a disastrous explosion might have resulted. The flame burned the packer's face and arms to some extent, and caused him to fall backward. In doing so, he let the lid of the bin fall, and thus cut off the flour dust inside the bin from the flaming dust outside.

The conditions and circumstances existing just previous to each of these various explosions were similar in all cases. From such observations as were made the conclusion has been reached that only under certain favorable conditions will a serious explosion of flour dust occur. If the dust is very dense and confined within a certain volume, or if the particles forming the dust are very large, the danger of a real explosion is less than in the case of the very fine, starchy dust in less density, which may, however, burn very rapidly. The theory is that these particles of a fine, starchy nature must be separated by a layer or thin wall of air, and at the same time be near enough together to ignite each other. Dense clouds of dust, especially those containing coarse particles, are comparatively slow burning.

A dust may also be very fine, yet so widely diffused as to be incapable of ignition, even from an open light. The old-fashioned dust room, sometimes merely partitioned off with fine muslin or other cloth, constituted a dangerous source of fire or explosion, as the dust blown from machines was held more or less in suspension before settling, and, being for the most part finely divided, it would be all the more dangerous should it come in contact with an open light.

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Contributions from the Bureau of Markets
CHARLES J. BRAND, Chief

Washington, D. C. ▼ July 15, 1918

A STUDY OF PRICES AND QUALITY OF CREAMERY BUTTER.

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IMPORTANCE OF ACCURATE WHOLESALE PRICE QUOTATIONS.

The majority of American creameries sell their butter on the basis of some recognized market quotation which, it is supposed, represents the prevailing wholesale market value of a certain grade of butter within the market where the quotation is issued.[1] The primary wholesale market receivers of creamery butter usually have standing agreements both with the creameries from which they obtain their supplies and with the jobbers and retailers to whom they sell, whereby the current prices for different grades of goods are dependent upon either weekly or daily market quotations. Thus, it is a matter of considerable importance to consumers as well as to producers that the various wholesale price quotations in different markets should reflect accurately the actual current values of different grades of butter.

METHOD AND SCOPE OF INVESTIGATION.

In order to determine the relationship of certain market quotations to the basic wholesale prices of creamery butter and to find out to what extent improvement in the quality of butter helps the creamery to obtain higher market returns, the Department of Agriculture made investigation of the sources of butter supply of various cities of the United States, the prevailing grade or quality of butter sold in different markets, and the prices paid for different grades. The investigations were begun in the spring of 1914 and continued until the fall of 1915. During that time over 1,000 creameries in all sections of the United States were visited by representatives of the department. The grade of butter they produced was determined, and additional information was obtained relative to their market outlets, the methods by which their outputs were marketed, and the prices obtained for various lots of different grades of butter shipped to different merchants within the same and different markets.

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[1] For a detailed description of the methods by which current market quotations are issued, see Department Bulletin 456, "Marketing Creamery Butter," by Potts, Roy C., and Meyer, H. F.

The sources of supply, the quality of butter demanded by different classes of trade, and the methods of market distribution were studied in more than 50 of the largest cities in every part of the United States. Various representatives of the department were engaged in this work, but all comparisons of quality between different creameries and different markets were based on the scorings of a single expert judge in the commercial grading of creamery butter.[1]

WHOLESALE QUOTATIONS ON WHICH CREAMERY BUTTER PRICES ARE BASED.

Creamery butter, which is properly made from a good grade of cream, will retain its desirable qualities for a sufficient time to permit it to be marketed at any season in practically any domestic or foreign market. Refrigeration and transportation facilities in the United States are such that it is possible to ship butter to practically every city in the country. Creamery men, however, like factory managers in other industries, generally have sought to sell their product in local markets as much as possible. Numerous cities in New England offer the best market outlets for the creameries in that section of the country. Likewise, the creameries of New York, and of Pennsylvania, as well as those of most of the Southern and Western States, have found satisfactory market outlets in the same regions in which they are located.

The production of creameries located in some sections of the country, particularly the North Central States, is greatly out of proportion to the local market demands of those regions. The great majority of creameries in that territory are located in rural districts where they have practically no local trade to supply, nor are there any neighboring cities which are not being adequately supplied by creameries situated in the same sections. Creameries thus situated are obliged to ship their product to large centers of population in the Eastern States or to some important storage and distributing center. New York, Chicago, and San Francisco are the most important market centers of this kind. Even those creameries which sell a large portion of their output in the cities in which they are located are obliged to find other market outlets where the local production is insufficient for the current trade demands. Boston is such an outlet for some of the large centralizing creameries of the Middle West. The accompanying map, figure 1, shows the location of the most important wholesale butter markets in relation to the general geographical location of a total of more than 4,000 creameries in the United States.

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[1] This investigation was made with the assistance of the Dairy Division, Bureau of Animal Industry, U. S. Department of Agriculture. Mr. M. P. A. Sondergaard, dairy manufacturing specialist of that bureau, inspected and scored the various lots of butter on which he was able to obtain first-hand knowledge regarding both buying and selling prices.

IMPORTANT BASIC WHOLESALE BUTTER MARKETS.

In the beginning of the creamery-butter industry of this country, the town of Elgin, Ill., was the center of the butter-producing region of the Middle West; and it was the place where representatives of butter merchants in eastern markets made offers for the product of the creameries in that section of the country. The prices at which goods were sold on the Elgin Board of Trade were published, and the quotations thus issued came to be regarded as the basic wholesale price of the American butter market. This was because most of the creameries in this region did not have local market outlets and therefore the major portion of "Elgin butter" was available for distribution in every city that had satisfactory transportation service and market connections with these creameries. As transportation and refrigeration facilities were improved, the creameries in the Elgin territory were able to compete for the markets of every important city in the country; and creameries in every part of the country sold butter at prices which were in line with the Elgin quotations.

Until recently[1] the custom of basing the buying and selling prices of creamery butter on the Elgin quotations still prevailed in many sections of the country, though the demands for market milk in Chicago and other neighboring centers of urban population had reduced the butter production in the "Elgin District" so that comparatively small quantities of butter were sold on the Elgin (butter) Board.

Chicago has become the leading market center for creamery butter produced in the Middle Western States, because, besides being a large consuming center, it has exceptionally good shipping and storage facilities. Many creameries and jobbers in that market

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[1] By action of the United States Food Administration the Elgin Board of Trade on October 31, 1917, suspended the issuance of butter quotations.

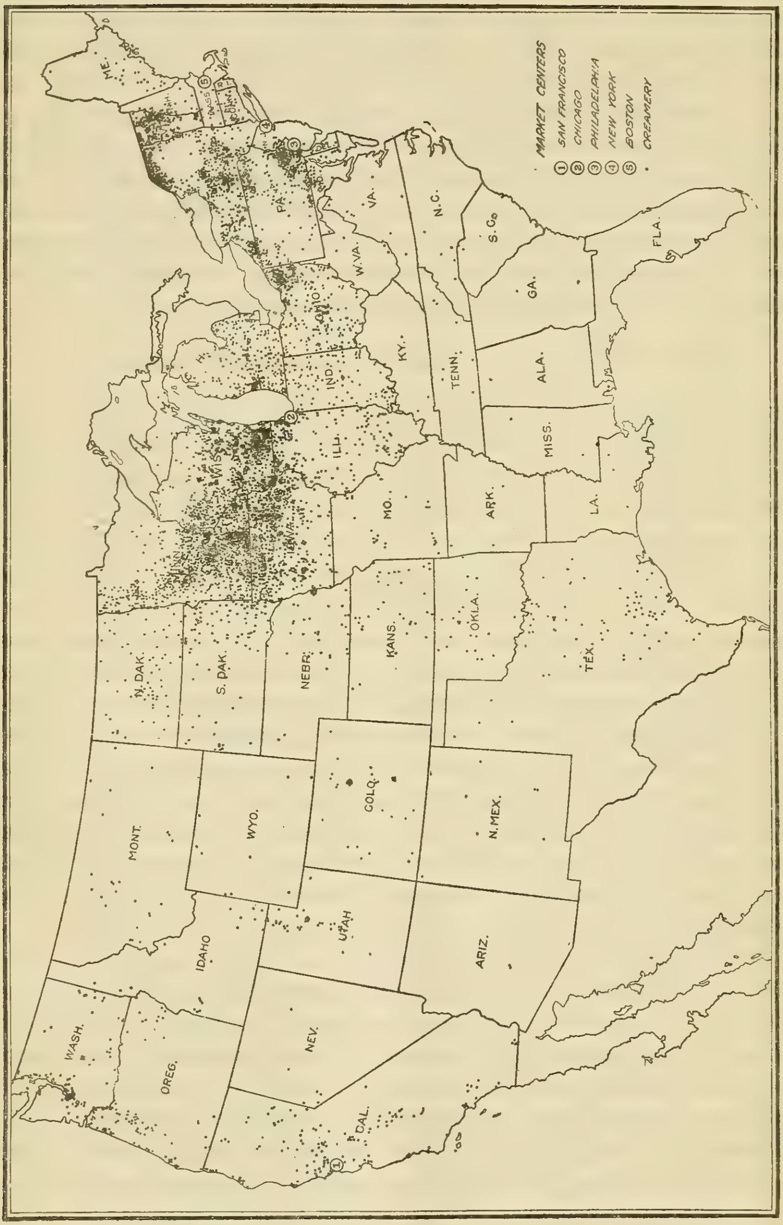

FIG. 1.—Showing location of creameries and important butter market centers of the United States.

territory are now basing their price agreements upon the Chicago quotations, because of the immense volume of daily receipts in that city and the fact that it is the chief center for reshipments to "out-of-town trade."

The other important wholesale markets for creamery butter are New York, Philadelphia, San Francisco, and Boston. The quotations issued in those cities serve not only as bases for settlements of market transactions within the territory supplied from these jobbing centers, but they are also the bases for price agreements between wholesale receivers and the creameries which ship to them. Although many of the creameries in the New England States no longer sell a large portion of their output to wholesale butter merchants in Boston, the custom of basing their selling prices on the Boston quotations still prevails.

RELATION OF WHOLESALE PRICE QUOTATIONS TO STANDARDS AND GRADES.

QUALITY STANDARDS.

To permit comparisons of market prices in different cities and to facilitate trading between different sections of the country, the various wholesale trade organizations in the chief wholesale butter markets of the United States have adopted grades and standards for butter. In wholesale market transactions butter generally is classified as "Creamery," "Dairy," "Ladles," and "Process," according to the method of manufacture; and "the trade" also recognizes different "grades" of creamery butter, such as "Higher scoring lots," "Extras," "Extra Firsts," "Firsts," and "Seconds," according to differences in the quality of various lots. The lack of uniform standards for the various "official grades" applying to certain wholesale market transactions is shown in Table 1.

Figure 2 presents a comparison of the average monthly wholesale price quotations for Extras in Boston, New York, Philadelphia, Chicago, Elgin, and San Francisco. It is evident that the prices, in the areas where production exceeds local consumption, differ from the prices in eastern market centers by approximately the costs of transportation. The experience of creamery men, however, has shown that the trade demands of different cities vary to such an extent that the standards of quality in the different markets are not actually the same, even when the accepted standards of different trade organizations, as shown in Table 1, are ostensibly alike. Hence the current market reports are not exact guides as to the prevailing wholesale prices of like grades of butter in different cities.

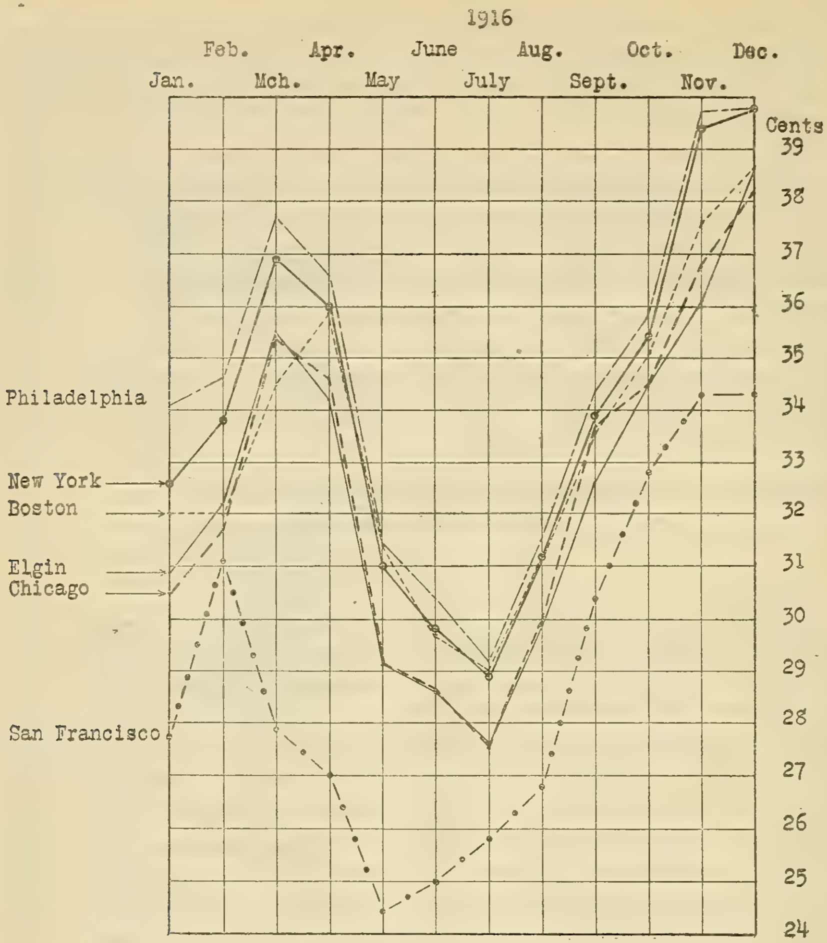

FIG. 2.—Average monthly quotations for extras in important wholesale butter markets.

TABLE 1.—*Comparison of the official creamery butter grades of different wholesale trade organizations.*

Grade.	Scores required for different grades.*					
	Boston.	Chicago.	Elgin.	New York.[1]	Philadelphia.	San Francisco.
Specials				93+		
Extras	93+	93+	93+	92	91+	93+
Extra first		91–92			90	[2] 90–92
Firsts	87–92	87–91		88–91	87–89	87–89
Seconds	80–86	80–90		83–87	80–88	80–89
Thirds	75–85	75–89		76–82	75–89	70–76

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* The plus sign (+) indicates that higher scores are included.

[1] At the discretion of a "Butter Committee" the scores required for various grades in the New York market are subject to change.

[2] Prime firsts.

QUALITY DEMANDS OF TRADE IN DIFFERENT CITIES.

In order to determine to what extent the "quality standards" of the trade differ in various markets, numerous lots of butter were sampled and scored in over 50 of the leading cities in all sections of the United States. The standard of quality of the "general run" of the market or the grade of goods which current market quotations generally represented was determined by a daily inspection of current arrivals in the storerooms of the wholesale trade. In figuring the average or the prevailing standard for any market, the scores of only such lots as were acceptable to the higher class of grocery trade in those cities were included. To check the inspections in the wholesale market, a number of sales were followed through to the consumer. The results of these studies of the comparative quality standards of the trade in the various important market centers of the United States showed differences of two or three points between the prevailing grades or the standards of the most discriminating eastern markets and those of certain western and southern cities.

In Table 2 the average scores of more than 150 different lots distributed among the retail trade of New York, Philadelphia, Chicago, St. Paul, and Minneapolis are shown. The first column is the average score of the representative lots of all butter sold to all classes of trade, and such scores are indicative of the "general run" of the market at that season of the year. The second column shows the average of lots sold only to the most select grocery trade, and such scores indicate the compartive standards for so-called "Extras" in those markets.

TABLE 2.—*Average scores for lots of creamery butter sold to all classes of trade and to select trade.*

[Based on scorings in winter months, 1914–15.]

Market.	All classes of trade.	Select trade.
New York	90.2	91.1
Philadelphia	90.8	91.8
Chicago	89.2	90.2
St. Paul and Minneapolis	89.1	89.6

The comparisons of the prevailing standards of the trade in the cities named above are based on the scorings of a single expert butter judge. This eliminates differences of personal tastes and makes the results of the work fairly comparable.

Although there is difference of opinion with regard to the comparative quality standards of different markets, the experience of most creameries has demonstrated the fact that the quality demands of the trade are different in different cities. Thus the majority of the country creameries of Minnesota have found that their shipments to Philadelphia and New York generally bring the highest net market returns. On the other hand, a large number of Iowa and Wisconsin creameries have found that their net price returns are usually the highest in the Chicago market. The tastes of different buyers vary, and, in the absence of uniform standards of quality, the wholesale price quotations of various market centers are not entirely reliable as guides for determining the most profitable market outlet for the output of any particular creamery. The only way in which a creamery man can determine the market in which his particular "make" of goods will net the highest market return is by the experiment of "splitting shipments" between different markets. It is through such trial shipments that most country creameries have selected their established market outlets.

SEASONAL CHANGES IN MARKET STANDARDS.

It is a well-recognized fact that the quality of output of most creameries varies with the season of the year. If the market standard were constant and inflexible, a large portion of the daily arrival during the spring season would grade as Extras, but the market standards are flexible and change somewhat in accordance with the quality of the general run of the current market receipts. According to the rules and regulations of the New York Mercantile Exchange, Extras may score 91, 92, or 93, according to variations in the quality of current receipts at different seasons of the year. The exact standard which is to prevail from time to time is determined by a committee of the exchange. None of the trade organizations of other cities has adopted this "seasonal sliding scale of standards"; nominally they adhere to a constant standard requiring a score of either 91 or 93 for Extras. (See Table 1.) A comparison of the average scores of lots which were representative of goods regularly accepted as Extras in both Chicago and New York showed, however, that the actual standards of the trade in both of those markets varied with the season of the year. In the winter of 1914–15, according to the scorings of current market receipts, the Chicago standard was approximately one point lower than the New York standard, although the nominal standard of the Chicago market was 93, as compared with a 92 standard in New York.

The difficulty of comparing Chicago quotations with those of New York is further increased by the fact that at certain seasons its trade demands change so that its standards are then practically the same as those of the New York market. The reason for this is that during the season of surplus production of creamery butter the demands of storage operators dominate the market situation. Many creameries in Minnesota which regularly ship to the New York market consign large quantities to Chicago each year during the storage season. They have found that on account of the demand for storage operations, the requirements of the Chicago market at that season of the year are equally as discriminative as those of New York. Since at this time the prevailing prices of butter are determined largely by the demands of those buying for storage purposes, the quality of butter demanded for storage becomes the basis of the current quotations, and thus the standards for surplus butter in Chicago and New York tend to coincide during the season when a large portion of current market receipts are bought for storage purposes.

RELATION OF WHOLESALE PRICES TO JOBBING AND RETAIL PRICES.

Buyers who are expert judges of differences in the quality of butter will pay varying prices for different lots which they have personally inspected, but the market reporters who collect the information upon which the various wholesale price quotations are based do not have general access to the records of private business transactions between the first-hand market receivers and jobbers or retailers. This situation has naturally raised a question as to the complete reliability of market reports or price quotations as issued under present conditions. The open sales "on exchange," which serve as a convenient basis for determining current quotations, generally amount to less than 5 per cent of the daily market transactions; and they are therefore considered insufficient to serve as a fair index of prevailing market values.

To check the relationship of quality to wholesale and retail prices, it was originally planned to compare the quality of certain representative lots of butter from known shippers with the prices paid by receiver, jobber, retailer, and consumer. It was found practically impossible, however, to arrange such cooperation on the part of the wholesale dealers as would permit the obtaining of reliable data on both the quality of butter and the prices at which it was sold in normal business transactions. During one week when this was attempted practically every lot from the creameries cooperating in this investigation was reshipped immediately upon its arrival in Chicago to jobbers in distant cities. Furthermore, receivers were reluctant to give names of buyers and the terms of sale on some lots because they feared that to do so might jeopardize their trade relations with some desirable customers.

It was deemed necessary, therefore, to reverse the method of investigation by observing the goods sold to retailers under normal market conditions. By this method it was possible also to study the quality of butter in relation to prices at which it was sold by various representative retail dealers located in different parts of the city which catered to various classes of trade. It was found impracticable, however, to trace any considerable number of lots from the retailer back to the creamery from which it had been shipped, because the creamery's stencil number usually is scraped off the tubs when they are weighed and inspected by the first-hand market receiver.

In Chicago, New York, Philadelphia, Minneapolis, and St. Paul an effort was made to check prices actually paid by various representative retailers with the current wholesale quotations for different grades of butter. To make the findings of these quality and price investigations comparable for the different cities, the buying and selling prices of all goods were compared with the New York wholesale quotations for Extras. No allowances were made for differences in freight rates from source of supply to these different cities; hence the average premiums paid in Chicago and the Twin Cities are considerably lower than those paid in New York and Philaedlphia. In fact, for oleomargarine, process butter, and the lower grades of creamery butter the prevailing prices were below those of New York Extras.

A comparison of the prices at which different grades of creamery butter and their substitutes were sold in New York, Philadelphia, Chicago, St. Paul, and Minneapolis is shown in Table 3. The comparison is based on the New York quotations for Extras, and the prices are expressed in margins of differences between the highest New York quotations and the prices paid by retailers and consumers in the other cities listed. Whenever the price was less than the New York quotation, the difference is expressed as a minus quantity; that is, the figures show the prevailing discount instead of the premium at which such goods were sold.

It is noteworthy that jobbing and retailing prices in general vary in accordance with the grade of goods. Table 3 shows, however, that the differences in prices of different grades of goods are not the same in all markets. In New York 80 lots of Firsts were bought by retailers at prices which on the average were 1.2 cents below those paid for Extras. In Philadelphia and Chicago, however, the differences between average prices for Extras and Firsts were 1.7 cents and 0.8 cent, respectively. Specially advertised brands, with established reputations for exceptional quality, were sold at retail at premiums averaging from 9.1 cents in New York to 14.2 cents in Philadelphia. While there was a general tendency in all markets for prices to vary in accordance with the quality of butter sold, there were occasional exceptions, however, especially in the case of buyers who based their judgment of quality mainly upon known stencil numbers or trademarks. For example, in Chicago the average retail price of 14 lots of Extras was lower than that of 159 lots of Firsts.

TABLE 3.—*A comparison of prices at which different grades of butter and butter substitutes were sold in New York, Philadelphia, Chicago, St. Paul, and Minneapolis.*

[Prices are expressed in margins of differences between highest New York quotations for Extras and the prices actually paid by retailers and consumers.]

Kind or grade.	New York.				Philadelphia.			
	Number of lots inspected.	Average price paid above or below New York Extras.		Average margins of profit.[1]	Number of lots inspected.	Average price paid above or below New York Extras.		Average margin of profit.[1]
		By retailer.	By consumer.			By retailer.	By consumer.	
		Cents.	*Cents.*	*Cents.*		*Cents.*	*Cents.*	*Cents.*
Extras	54	3.8	9.1	5.2	35	5.4	11.2	6.6
Firsts	80	2.6	6.6	4.3	35	3.7	8.8	6.1
Seconds	28	1.0	3.9	3.8	24	.4	2.3	5.0
Special brands	23	15.4	21.9	6.5	34	14.2	23.6	6.9
Unclassed	8	2.9	6.9	4.6	9	3.8	9.3	7.1
Totals[1]	193	3.6	8.0	4.7	137	7.2	11.9	6.0
Process	5	— 4.4	.5	4.7	....	....	....	....
Oleomargarine	12	—12.6	— 6.7	5.8	4	—11.5	— 6.9	6.1
	Chicago.				Minneapolis and St. Paul.			
Extras	14	1.1	3.0	4.5	37	1.3	6.4	5.4
Firsts	159	.3	3.9	3.5	219	— .8	4.5	4.8
Seconds	107	— .5	1.9	3.3	70	— 3.2	1.6	4.5
Unclassed	24	— .3	3.3	3.4	39	— 1.7	4.4	5.4
Totals[1]	213	+ .05	3.0	3.9	365	— 1.14	4.12	4.86
Process	4	— 7.1	....	....	2	— 6.9	— 1.9	5.0
Oleomargarine	56	—12.8	....	....	26	—14.4	— 8.9	5.2

[1] Since both cost and selling prices were not obtained on some lots of butter the averages of prices and margins of profit do not always check.

Table 3 may not represent accurately the general differences in values of different grades of butter at all seasons of the year, because market demands and prices for different grades usually vary in accordance with changing conditions of the market supply. It is a noteworthy fact, however, as has been stated (p. 9), that the present published market quotations are not based on the sales records of a large number of representative lots of different grades of butter and that the open sales on exchange constitute a very small part of the total wholesale transactions, and that the prices applying to the bulk of the daily market transactions are based rather upon these published quotations.

RETAIL PRICE LEVELS.

DIFFERENCES BETWEEN CITIES, DUE TO SPECIAL CONDITIONS.

A general correspondence of wholesale butter prices in the large distributing centers of the United States is shown in figure 2. Tables 1 and 2 show that the published wholesale quotations upon which the price curves in figure 2 are based may not present an accurate comparison of actual market values of exactly the same grades of butter; but either actual or potential competition between numerous creameries producing in excess of local market demands has tended to establish a fundamental level of prices between such market centers. The retail prices in some of the cities of the country, however, may sometimes be out of line with the basic prices of the larger butter-distributing centers: First, because definite and dependable market reports on creamery butter are not available for many cities in different parts of the country; and, second, because country creameries generally have no direct trade connections in such cities. Most country creameries can choose only between such large wholesale distributing centers as New York, Philadelphia, Chicago, and San Francisco. There are not many wholesale butter merchants in any other American cities who have won the patronage of a large number of creameries, and consequently there is little direct competition between different creameries for market outlets in a large number of different cities. This lack of direct competition between a large number of different creameries for various market outlets in various cities has enabled certain large centralizer creameries, which maintain their own distributing organizations in cities like Denver, Colo., Omaha, Nebr., Sioux City, Iowa, St. Paul and Duluth, Minn., Detroit, Mich., Milwaukee, Wis., and Columbus, Ohio, to sell at prices which temporarily may be higher than those received by some local country creameries.

Figure 3 compares the prevailing average retail prices of creamery butter in some of the larger cities of the United States. These prices are based on the reports of representative retail grocers which are made monthly to the Bureau of Labor Statistics,[1] United States Department of Labor. Although there are differences in prices reported by different retailers within the same city, the average yearly prices show that, on the whole, consumers generally pay higher prices for butter in some cities than in others.

The variations in the margins between the lines which show the retail prices in the various cities and the line which shows the basic Chicago wholesale quotation, represent roughly the differences in transportation costs from various sources of supply. The combined costs and profits of both the wholesale and retail distribution within a city, are indicated by the margin of difference between the wholesale price quotations of Chicago and the average of the prevailing retail prices in that city.

COMPETITION BETWEEN COUNTRY CREAMERIES AND CENTRALIZERS.

As a rule the wholesale prices of centralizer creameries are in line with the Chicago quotations, except for occasional increases

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[1] Bulletin 84 of the U. S. Bureau of Labor Statistics, entitled "Retail Prices of Food, 1915–1916."

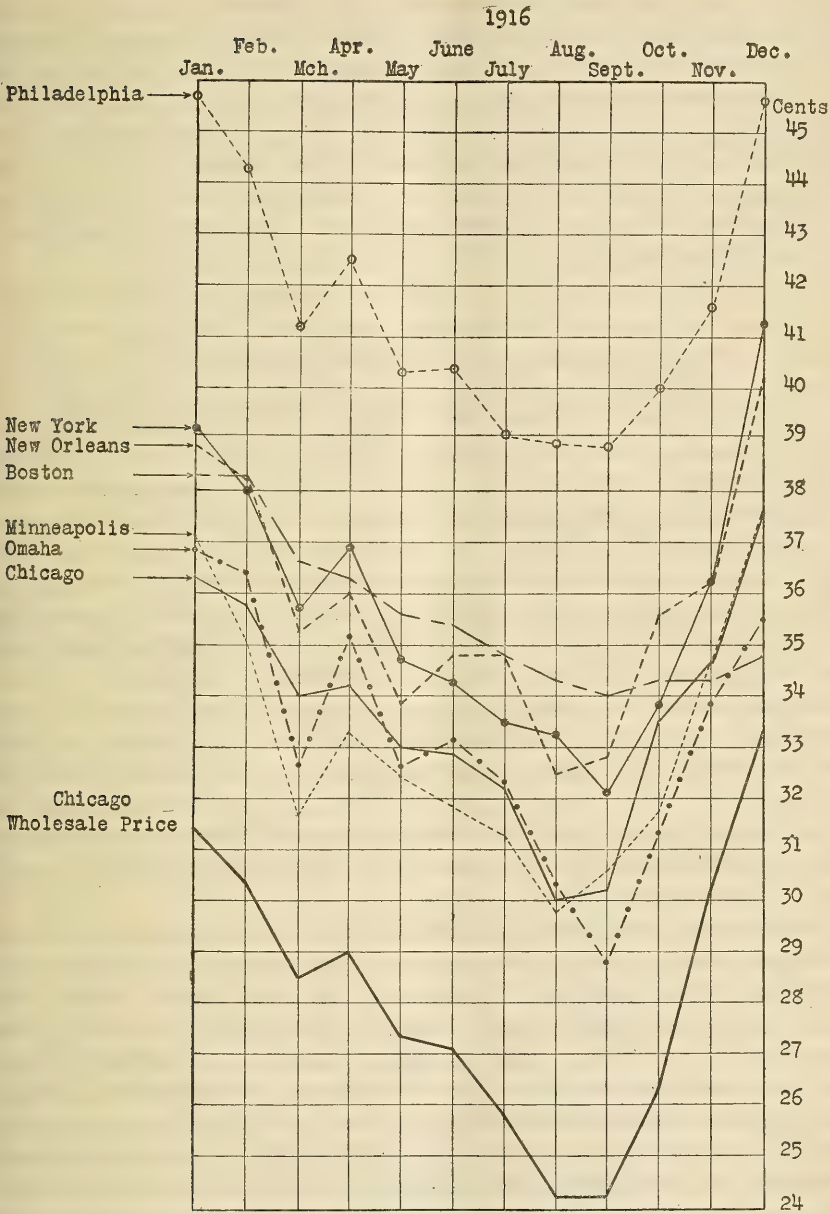

FIG. 3.—Comparison of average monthly retail prices of creamery butter in a number of cities with the Chicago basic wholesale quotation for extras.

when local competitive conditions permit. During the year 1914, when representatives of the department were investigating marketing conditions in the Middle West, it was found that the creameries in St. Paul, for example, were receiving at certain seasons higher prices than neighboring country creameries which shipped to Chicago. More than 375 lots of butter, which were scored in 103 representative retail stores, hotels, and restaurants in St. Paul and Minneapolis, showed that, for the best grade of country creamery butter in that market, certain retailers catering to a select class of trade were paying practically 2 cents per pound more than the usual price for the prevailing grades of both country creamery and centralizer butter in that market.

Only a small portion of the total requirements of those two cities, however, was supplied by country creameries. Retail grocers generally made no attempt to select their purchases on the basis of quality. Individual retailers usually restricted their dealings to a single centralizer creamery which supplied them regularly two or three times a week with freshly churned goods. Some of them stated that they believed that certain country creameries could supply them with a better grade of butter, but they had found that consumers generally preferred the attractive retail packages of well-advertised brands which were supplied by large centralizer creameries. Even though expert judges of butter were able to detect superiority in the quality of some of the country "make," retailers and consumers generally did not notice any decidedly "off flavors" in the brands furnished by the local centralizers. This was because they were in a position to deliver freshly churned stock three or four times a week. The difference in quality between some country creamery stock and the current supply of centralizer brands was slight at that season of the year. The average score of 120 lots of country creamery butter was 89.96, as compared with a score of 89.39 for 220 lots of centralizer brands.

Under such conditions it is difficult for country creameries to gain a dependable market outlet in cities where certain large creameries have developed a demand for their own make of goods. When outside creameries begin to make large shipments to such cities, prices are immediately forced down, because of the lack of established out-of-town trade connections. Unless creameries of the Middle Western States, where butter is constantly produced in excess of local demands, establish local concentrating points with facilities for grading and storing, and with widely ramifying trade connections in many sections of the country, their choice between dependable market outlets is practically limited to such wholesale markets as Chicago, New York, Boston, and Philadelphia.

EFFECT OF PACKAGING UNDER ESTABLISHED BRANDS.

As a result of the studies in the retail markets of larger cities in his country, it was found that most retailers, as well as consumers generally, do not buy butter on the basis of grades[1] as determined by fficial inspectors or expert judges of butter. Being usually unskilled udges of quality, they are guided largely by their experience with arious stencil numbers or advertised brands or trade-marks. As a esult of this practice, many creamery men whose butter is not sold nder a distinctive trade-mark have come to believe that consumers ay for the brand and not the quality of goods. In Table 4 the verage quality scores and retail prices of the different lots of bulk nd trade-marked butter found in retail stores are compared.

ABLE 4.—*Comparison of quality (average score) and average retail price of branded and unbranded butter.*

[Retail prices expressed in margins between prices paid and local quotations for Extras.]

Market.	Branded lots.			Unbranded lots.		
	Number of lots.	Average score.	Price margin.	Number of lots.	Average score.	Price margin.
			Cents.			*Cents.*
ew York	60	91.2	11.1	122	89.8	8.83
hiladelphia	80	90.8	11.6	21	90.7	9.02
hicago	161	89.6	6.1	68	88.7	4.7
t. Paul and Minneapolis	230	89.3	5.18	37	89.7	5.06

It will be noted in this table that no definite relation appears to xist between quality and retail prices. Except for New York and hiladelphia, where many consumers are exceptionally discriminative r appreciative of good quality, there seems to be a tendency for conumers to pay more for trade-marked goods put in print packages han for unbranded "bulk" goods, regardless of any fine differences n quality. The average prices given in the table for "print" or rade-marked butter for New York and Philadelphia include a limted number of "special brands" made from either whole milk or ream of an exceptionally high quality. Such "special brands" are ot marketed by the usual system of distribution employed by the ajority of country creameries, but generally are sold "direct from actory to retailer" or through the manufacturer's own retail stores r delivery wagons. The prices obtained for butter sold under these rands, as shown by Table 3, ranged from 8 to 12 cents higher than hose of Extras marketed through the usual system of distribution r local creamery butter.

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[1] For a description of commercial practices in grading butter, see U. S. Department of griculture Bulletin 456, "Marketing Creamery Butter," by Potts, R. C., and Meyer, . F.

Thus it is seen that while expert judges of quality will pay high prices for butter of exceptional quality and that while the local country creamery marketing system does differentiate between different grades of butter, the highest grades do not always retail at the highest prices. Many lots of country creamery butter, scoring equally as high as samples of "special brands," were retailed at prices 5 or 6 cents per pound lower.

EFFECT OF DIFFERENCES IN TYPE OF RETAILERS.

In Table 3 it is shown that some retailers made larger margins of profit by selling butter substitutes than they did by selling the ordinary grades of creamery butter. It is noteworthy, however, that as a general rule most retailers took a larger margin on the higher grades of butter than they did for Firsts or Seconds. Not all retailers aim to handle butter at a profit, for many grocers sold butter at unusually small margins in order to draw trade for other goods which presumably were being sold at fair margins of profit. Table 5 gives some comparisons in the volume of business, the kind of butter and butter substitutes handled, the comparative selling prices, and the margins at which butter was handled by different kinds of retail establishments.

MUNICIPAL MARKET STANDS.

The retail stands in public or central market places had the largest average weekly sales. These stands, like the dairy stores, generally sold only dairy products and eggs. Another distinguishing characteristic of this class of retail stores is that they make no deliveries of goods and all sales are for cash. In Philadelphia and New York this class of retailers supplied a considerable portion of the more discriminating class of consumers who exercise care in selecting their goods. The quality of a large portion of butter handled by this class of dealers was necessarily exceptionally high to meet the demands of their trade. (See Table 5, p. 18.)

DELICATESSEN STORES.

Under the class designated as delicatessen stores are included small family grocery stores which do not maintain a delivery service and whose average weekly sales are comparatively small. In the aggregate the percentage of the consumers in Chicago and New York who secure their butter supply as well as other staple groceries from this type of stores is large. Retailers of this class were found to be the poorest judges of quality in the goods they bought, and their average buying and selling prices were higher than those of dealers of any other class. In some cities many of these small retailers have sought to overcome this handicap through an arrangement whereby all purchases are made by a single buyer who is an expert judge of butter. By centralizing their purchasing they also obtain the advantage of reduced prices on account of larger purchases. (See Table 5, p. 18.)

GROCERY STORES.

For the purpose of these comparative studies all stores which maintain regularly a telephone order department and a daily delivery service and which were not units of a chain store system were classified as "grocery stores." Another important characteristic of this class of stores is the fact that they usually carry many of their customers on monthly or biweekly credit accounts. In most cities the bulk of all retail sales of butter is made by stores of this type. It is noteworthy that the average selling price of independent grocery stores was higher than that of retail chain store systems. (See Table 5, p. 18.)

CHAIN STORES.

The greater portion of the butter supply of Philadelphia is sold through chain stores. These stores do not generally maintain a telephone service, and practically all sales are for cash. The distinctive characteristic of the chain-store system is the fact that the purchasing of all supplies is centralized; and thus "the system" has the advantage of having its supplies selected by expert judges of quality and reduced prices for large bulk purchases. The investigation showed that in Philadelphia this class of stores obtained Extras at an average of 2 cents below the prevailing prices paid by other classes of retailers. (See Table 5, p. 19.)

WAGON RETAILERS.

Retail hucksters or wagon peddlers who specialize in selling dairy products and eggs handle an extremely small percentage of the butter supply of any city. Special mention of this class of retailers is made because a few creameries have been able to obtain an exceptionally good price for a good grade of butter supplied in accordance with the regular demands of the customers served by them. Because of the comparatively small amount of their purchases, wagon retailers generally can not buy as cheaply as chain-store operators. (See Table 5, p. 19.)

DAIRY AND FRUIT STORES.

In New York and Boston a considerable number of small dairy stores are operated by fluid milk distributing concerns which also sell manufactured dairy products, eggs, honey, and other delicacies. In Chicago and other cities fruit stores also sell considerable quantities of butter. These two types of stores are classed together for the purposes of this study because they sell approximately equal quantities of butter, and the terms of sales in each case are cash. Neither the fruit nor the dairy stores make deliveries. (See Table 5, p. 19.)

HOTELS, CLUBS, AND RESTAURANTS.

Clubs, hotels, and restaurants are not retailers of butter, but records of purchases of this class of "wholesale consumers" of butter were obtained for purposes of comparison with those of retailers. The quality of the butter purchased by New York and Philadelphia restaurateurs was comparatively much better than that purchased by those of Chicago, Minneapolis, and St. Paul. Some well-known hostelries were able to buy at relatively low prices because of the advertising value of their patronage to the jobber. (See Table 5, p. 19.)

TABLE 5.—*Proportionate sales of butter and oleomargarine in relation to average cost prices and margins of gross profit of retailers and hotels, etc.*

15 REPRESENTATIVE MUNICIPAL MARKET STAND RETAILERS IN NEW YORK AND PHILADELPHIA.

Commodity sold.	Weekly sales.[1]	Per cent of total weekly sales.	Average cost price.[2]	Retailers' gross profit.
	Pounds.	*Per cent.*	*Cents.*	*Cents.*
Common creamery butter sold in bulk	1,043	45	1.5	6.13
Common creamery butter sold in trade-marked cartons	742	32	4.2	7.96
Special quality brands sold in cartons	533	23	16.0	5.13
Total for all creamery butter	2,318	100	13.2	6.4
Process butter	0	0		
Oleomargarine	0	0		

110 REPRESENTATIVE DELICATESSEN STORES IN NEW YORK, PHILADELPHIA, CHICAGO, ST. PAUL, AND MINNEAPOLIS.

Commodity sold.	Weekly sales.[1]	Per cent of total weekly sales.	Average cost price.[2]	Retailers' gross profit.
Common creamery butter sold from tubs	26.5	32	3.7	3.0
Common creamery butter sold in trade-marked cartons	45.6	55	6.0	4.7
Special quality brands sold in cartons	8.3	10	14.0	5.0
Total for all creamery butter	80.4	97	7.9	4.2
Process butter	.8	1	− 2.0	3.2
Oleomargarine	1.6	2	−13.7	7.5

165 REPRESENTATIVE GROCERY STORES IN NEW YORK, PHILADELPHIA, CHICAGO, ST. PAUL, AND MINNEAPOLIS.

Commodity sold.	Weekly sales.[1]	Per cent of total weekly sales.	Average cost price.[2]	Retailers' gross profit.
Common creamery butter sold in bulk	126	33	2.2	3.6
Common creamery butter sold in trade-marked cartons	214	56	4.0	5.4
Special quality brands sold in cartons	8	2	20.0	6.9
Total for all creamery butter	348	91	8.7	5.3
Process butter	4	1	− 7.0	6.9
Oleomargarine	30	8	−10.5	4.9

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[1] Average per retailer.

[2] Prices are expressed in margins of differences between cost prices of all grades of butter and oleomargarine and the highest New York quotations for Extras on the date of purchase. Proper allowance for transportation costs were made in cases of purchases in Chicago, St. Paul, and Minneapolis.

TABLE 5.—*Proportionate sales of butter and oleomargarine in relation to average cost prices and margins of gross profit of retailers and hotels, etc.*—Con.

36 CHAIN STORES IN NEW YORK, PHILADELPHIA, CHICAGO, ST. PAUL, AND MINNEAPOLIS.

Commodity sold.	Weekly sales.[1]	Per cent of total weekly sales.	Average cost price.[2]	Retailers gross profit.
	Pounds.	*Per cent.*	*Cents.*	*Cents.*
Common creamery butter sold in bulk	494	54	0.7	3.0
Common creamery butter sold in trade-marked cartons	329	36	1.9	3.3
Special quality brands sold in cartons	0	0	....	....
Total for all creamery butter	823	90	1.3	3.1
Process butter	9	1	− 6.0	4.0
Oleomargarine	82	9	−11.5	5.2

9 WAGON RETAILERS IN PHILADELPHIA, ST. PAUL, AND MINNEAPOLIS.

Common creamery butter sold in bulk	485	49	2.2	5.0
Common creamery butter sold in trade-marked cartons	346	35	5.5	6.0
Special quality brands sold in cartons	158	16	15.0	5.0
Total for all creamery butter	989	100	7.5	5.3
Process butter	0	0	....	....
Oleomargarine	0	0	....	....

30 DAIRY AND FRUIT STORES IN NEW YORK, PHILADELPHIA, CHICAGO, ST. PAUL AND MINNEAPOLIS.

Common creamery butter sold in bulk	826	61	2.3	4.5
Common creamery butter sold in trade-marked cartons	244	18	5.3	5.9
Special quality brands sold in cartons	26	2	13.2	8.3
Total for all creamery butter	1,096	81	6.9	6.2
Process butter	13	1	− 6.0	5.0
Oleomargarine	244	18	−14.0	4.9

35 HOTELS, CLUBS, AND RESTAURANTS IN CHICAGO, ST. PAUL, AND MINNEAPOLIS.

Kind of commodity purchased.	Purchased weekly.[4]	Per cent of total purchases.	Average cost price.[3]
	Pounds.	*Per cent.*	*Cents.*
Common creamery butter purchased in bulk	14.0	15	−1.5
Common creamery butter purchased in trade marked cartons	74.5	81	−0.8
Special quality brands purchased in cartons	0	0	....
Process butter	3.6	4	−7.8
Oleomargarine	0	0	....

[1] Average per retailer.

[2] Prices are expressed in margins of differences between cost prices of all grades of butter and oleomargarine and the highest New York quotations for Extras on the date of purchase. Proper allowance for transportation costs were made in cases of purchases in Chicago, St. Paul, and Minneapolis.

[3] Average per restaurant.

SUMMARY OF RETAIL SALES RECORDS.

Table 5 shows that oleomargarine, process butter, and special brands of creamery butter in most cases constitute only a small portion of the total sales of all kinds of butter and butter substitutes. Different stores within the same class of retailers handle different "makes" or "brands," but there seems to be a tendency among groceries and delicatessen stores to give preference to well-known and widely advertised brands. This is shown by the proportion of common creamery butter which is sold under advertised brands. The greatest portion of "special brand" butter was sold through high-class grocery stores, central-market stands, dairy stores, and wagon retailers. The largest sales of oleomargarine were made by certain retail fruit stores in Chicago.

From the records of retail grocery stores and wagon dealers, who sold largely "on credit" to over 20,000 families, it was possible to compare the weekly butter purchases of various classes of trade, including the poorest and the most well to do. The average weekly consumption per family for the different classes of trade was as follows: Poor class, 1.48 pounds; middle class, 1.97 pounds; well-to-do class, 1.60 pounds. The average weekly purchases of the middle-class customers of New York were somewhat larger than those of the other cities in which these studies were conducted. It is important to note that these figures were based on the current sales during the winter season, when butter prices are the highest of the year. There was evidence to show that during the season of decreased prices many families buy butter which do not use it in winter, and that many families which use butter the year around increase their average weekly purchases during the season of reduced prices.

The average prices of common creamery butter sold in retail stores that catered mainly to the poorer classes of laboring people were generally higher than the prices charged by stores whose customers consisted mainly of the better paid class of workingmen, clerks, and professional people. This may be explained, in part at least, by the fact that the stores serving the poorer classes of working people were mainly of the delicatessen or the small corner grocery type, which were usually unable to buy as cheaply as those retailers who purchased their supplies in comparatively large quantities.

CONCLUSIONS.

There are considerable differences in the prices of creamery butter in different cities of the United States, but the wholesale prices in all cities follow rather closely the current wholesale prices at which the surplus production of the creameries of the Middle West is sold on the larger wholesale markets. Differences in distance from the sources of supply to the various markets, and hence in transportation costs, account for most of the wholesale price variations between different cities. There are variations in prices paid by different merchants in various cities, however, which find their explanation in the differences in consumers' tastes and buying powers.

An important function of an efficient butter marketing system is to effect such a distribution of the various grades of butter produced in various parts of the country that the product of each factory may be sold in the particular city or section of a city where it will bring the highest return to the producer. Improvement in sources of market information would facilitate such an equitable distribution of the output of more than 4,000 creameries which are individually too small to maintain their own sales organizations in distant markets. Under the prevailing system of marketing country creamery butter, however, market returns to creamerymen are based upon market quotations issued by market reporting agencies, and a method of grading which is controlled by the wholesale butter merchants themselves. A system of butter inspection and grading operated under the supervision of the Federal Government,[1] available to shippers of creamery butter and wholesale and retail distributers, would tend to facilitate the market distribution of creamery butter on an equitable quality basis. A market-reporting service on creamery butter was recently established by the Bureau of Markets of the United States Department of Agriculture; and many creameries and wholesale market receivers are relying upon the daily market reports issued as a basis for guiding their marketing operations. The price reports[2] issued by the Bureau of Markets are based upon actual sales of various lots of butter of different grades of quality, and an average price is quoted for each score rather than a range of prices covering the scores included within the different market grades. (See Table 1.)

These studies of quality and prices of creamery butter show that the highest retail prices are paid for creamery butter which is sold under a trade-mark or brand that is generally recognized among consumers as a guaranty of uniform excellence of quality. Generally, however, only those creameries which are located in large cities or whose outputs are sufficient to enable them to establish their own marketing organizations in distant centers of population have been able to arrange to have their butter sold under their own distinctive brands or trade-marks. The unusually high prices obtained for certain "special brands" of butter sold in Philadelphia and New York suggest the possibility of increasing greatly the market returns of creameries making "States Brand Butter," provided such butter is sold to the consumers under the exclusive brands of the creameries.

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[1] Authority for establishing such an inspection service was provided for in H. R. 4188, Sixty-fifth Congress, approved Aug. 10, 1917.

[2] The Bureau of Markets' price reporting service on creamery butter was authorized by Congress in H. R. 4188, Sixty-fifth Congress, which provided for "enlarging the markets news service" of the Bureau of Markets as a war-emergency measure. Branch offices have been established in the four important wholesale butter markets—Boston, New York, Philadelphia, and Chicago—and through these offices and others to be established, daily butter-market bulletins showing both wholesale and jobbing prices of creamery butter in these markets, the cold-storage movement, and supplies of fresh butter on the market are issued. These bulletins are distributed free to all who make requests for them.

Retailers and consumers might also, with advantage to themselves, improve their buying methods. Small grocers and proprietors of delicatessen shops often pay higher prices for butter of comparatively inferior quality than larger dealers pay for butter of choice quality. Cooperative buying associations among the retailers of some cities in which an expert judge of butter quality does the buying have overcome some of the difficulties encountered by retailers who buy as individuals in competition with the larger retailing organizations.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 683

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. ▼ **July 29, 1918**

UTILIZATION OF ELM.

By W. D. BRUSH, *Scientific Assistant.*

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IMPORTANCE.

Elm is one of the important commercial woods of the United States. It is important, however, not so much because of the amount consumed annually, for 8 or 10 hardwoods and an even greater number of softwoods are used in larger quantities, as because it has qualities which make it especially desirable for bent work and for uses in which it is subjected to shock or impact and rough usage in general. It is particularly suited for slack-cooperage stock, certain parts of vehicles, baskets, and crating.

COMMERCIAL SPECIES.

The following five species produce the supply of elm wood in the United States: White elm (*Ulmus americana*), slippery elm (*Ulmus fulva*), cork elm (*Ulmus racemosa*), wing elm (*Ulmus alata*), and cedar elm (*Ulmus crassifolia*). The proportion which each contributes to the lumber industry is not known, since they are often mixed together and are all generally listed as "elm" in reports of manufacturers of elm lumber and elm products.

White elm is by far the most important species in the production of elm wood. It often goes under the name "gray elm" in the Lake States, and in foreign countries is called "American elm" and "Canadian elm."

Slippery elm is so called from its thick mucilaginous inner bark, which distinguishes it from the other elms. The name "red elm" is also applied to it. This species is second in importance. Since the wood is quite similar to white elm and the tree is found in practically the same regions, it is generally marketed with white elm under the same name.

Cork elm, which takes its name from the corky excrescences or growths on the twigs, is also an important commercial species. It is called "rock elm" in the trade. This name is also applied to hard, dense, rapid-growth wood of other species; in fact, very dense wood of any species of elm is called rock elm, and the softer, more porous wood is called "soft elm." Very porous elm wood is often termed "water elm" or "swamp elm."

Wing elm takes its name from the corky growths on the twigs similar to those on cork elm, which in this species are thin and winglike. Wing elm is of small importance commercially.

Cedar elm, often called "red elm" and in Arkansas "basket elm," is utilized only in a small way, and much of it is not large enough to manufacture into lumber.

CHARACTERISTICS OF THE WOOD.

GENERAL APPEARANCE.

The heartwood of elm is light brown, often tinged with red; the sapwood is lighter. The wood has a fairly distinct and somewhat attractive figure, which is due to bands of pores occurring at the beginning of each annual layer of growth. This figure is inconspicuous in rock elm because of the smaller size of the pores. The figure varies considerably with the width of annual rings, wood with annual growth layers moderately wide usually yielding the most attractive material. Radial cuts do not give the quartered effect of oak because of the comparatively narrow pith rays. Tangential surfaces present the most pleasing appearance.

MECHANICAL PROPERTIES.

The wood of all species of elm is in general heavy, hard, strong, and has in a high degree the ability to withstand shock. It is difficult to split, except slippery elm. It shrinks moderately in seasoning, is one of the best woods for bending, and takes a good polish. Table 1 gives the properties of the three principal elm woods expressed in comparative terms. Table 2 shows the results of tests to determine the mechanical properties of the elms, with data for several hickories included for comparison. The table also gives the values of these woods compared to oak. Similar data for wing and cedar elm are not available. Table 3 gives, for different elms, the average computed weight of 1-inch lumber, the weight of a cord of wood, and the weight of logs per thousand board feet as scaled by the Doyle and Scribner log rules. In this table the cord is calculated as being composed of 90 cubic feet of solid wood. The weight adopted by the Hardwood Manufacturers' Association of the United States for rough white elm lumber 1 inch thick is 3,200 pounds per thousand board feet. Comparison of this with the figures given in Table 3 shows that the association weight is for lumber in a partially air-dry condition. A weight of 3,200 pounds per thousand board feet corresponds to a moisture content of about 16.4 per cent, and air-dry wood usually varies between 12 and 15 per cent. Similarly, the weight adopted by the same association for rough cork elm lumber is 3,800 pounds per thousand, which is somewhat higher than that given in Table 3.

In general, cork elm has higher strength values than white elm, and slippery elm has values between the two. Both white and slippery elm have lower strength values than white oak (excepting the shock-resisting ability of slippery elm), particularly in compression perpendicular to grain and hardness. The values for cork elm do not vary greatly from those for white oak, except in shock-resisting ability, which is much higher in cork elm. The elms all rank lower than the hickories in mechanical properties. A good quality of cork-elm wood should, however, make a fairly satisfactory substitute for hickory where these properties are of first consideration, as for long heavy handles, the running-gear parts of light vehicles, eveners, etc.

Elm is a fairly durable wood. The estimated average life of untreated elm lumber in the United States in situations exposed to the weather is from 6 to 8 years. The durability of any individual stick, however, may vary from this figure, depending on the quality of the wood and the moisture conditions. White elm is said to be somewhat less durable in contact with the soil than slippery elm. It is highly desirable to treat elm where it is to be used in exposed situations. By proper treatment with creosote its life may be lengthened to 20 or more years.

TABLE 1.—*Properties of elm woods expressed in comparative terms.*

Property.	White elm.	Slippery elm.	Cork elm.
Weight	Moderately heavy	Moderately heavy	Heavy.
Shrinkage	Moderate	Moderate	Moderate.
Strength	Moderately strong	Moderately strong	Strong.
Stiffness	Moderately stiff	Moderately stiff	Moderately stiff.
Hardness	Moderately hard	Moderately hard	Hard.
Shock-resisting ability	Good	Good	Excellent.
Cleavability	Poor	do	Poor.

TABLE 2.—*Average mechanical properties of elm woods, actual and comparative.*

[Based on tests of small clear specimens in a green condition.]

Common and botanical name.	Locality where grown.	Weight per cubic foot.			Shrinkage from green to oven-dry condition.			Strength in bending (per square foot).	
		Green.	Air-dry.	Kiln-dry.	In volume.	Radial.	Tangential.	Modulus of rupture.	Relative strength compared to oak. (oak=100).
		Pounds.	*Pounds.*	*Pounds.*	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*	
White elm (*Ulmus americana*)	Pennsylvania and Wisconsin	52	35	33	14.4	4.2	9.5	6,900	83
Slippery elm (*Ulmus fulva*)	Indiana and Wisconsin	56	38	37	13.8	4.9	8.9	8,000	96
Cork elm (*Ulmus racemosa*)	Wisconsin	54	45	43	14.1	4.8	8.1	9,500	114
Shagbark hickory (*Carya ovata*)	Ohio, Mississippi, Pennsylvania, West Virginia.	64	52	50	16.7	7.0	10.5	11,000	133
Pignut hickory (*Carya glabra*)	Ohio, Mississippi, Pennsylvania, West Virginia.	64	55	53	17.9	7.2	11.5	11,700	141
Mockernut hickory (*Carya alba*)	Pennsylvania, Mississippi, West Virginia.	64	53	50	17.9	7.8	11.0	11,110	134

TABLE 2.—*Average mechanical properties of elm woods, actual and comparative*—Continued.

Common and botanical name.	Locality where grown.	Strength in compression parallel to grain (per square inch).		Strength in compression perpendicular to grain (per square inch).		Stiffness per square inch.		Side hardness.		Shock-resisting ability (per cubic inch).	
		Maximum crushing strength.	Relative strength compared to oak(oak=100).	Fiber stress at elastic limit.	Relative strength compared to oak(oak=100).	Modulus of elasticity in bending.	Relative stiffness compared to oak(oak=100).	Load required to embed a 0.44-inch ball one-half its diameter.	Relative hardness compared to oak(oak=100).	Work to maximum load in bending.	Shock-resisting ability compared to oak(oak=100).
		Pounds.		*Pounds.*		*1,000 lbs.*		*Pounds.*		*Inch-lbs.*	
White elm (*Ulmus americana*)	Pennsylvania and Wisconsin	2,860	80	390	47	1,030	82	530	50	11.0	96
Slippery elm (*Ulmus fulva*)	Indiana and Wisconsin	3,310	93	510	61	1,230	98	660	62	15.4	134
Cork elm (*Ulmus racemosa*)	Wisconsin	3,770	106	740	89	1,200	96	970	92	19.7	171
Shagbark hickory (*Carya ovata*)	Ohio, Mississippi, Pennsylvania, West Virginia.	4,580	129	1,000	120	1,570	125	....	....	23.7	206
Pignut hickory (*Carya glabra*)	Ohio, Mississippi, Pennsylvania, West Virginia.	4,810	135	1,140	137	1,650	132	....	....	31.7	276
Mockernut hickory (*Carya alba*)	Pennsylvania, Mississippi, West Virginia.	4,480	126	1,000	120	1,570	125	....	....	26.1	226

TABLE 3.—*Computed weights of elm in different forms.*

Kind of elm.	1,000 feet b. m. of 1-inch lumber.	Cord (90 cubic feet solid wood).	1,000 board feet of logs.							
			Doyle log rule: diameter of logs (inches)—				Scribner log rule: diameter of logs (inches)—			
			6	12	18	24	6	12	18	24
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
White elm, green	4,300	4,700	55,600	12,000	8,400	7,100	12,400	9,700	7,700	7,000
White elm, air-dry	2,900	3,200	37,400	8,100	5,600	4,800	8,300	6,500	5,200	4,700
Slippery elm, green	4,700	5,000	59,900	12,900	9,000	7,600	13,300	10,500	8,300	7,600
Slippery elm, air-dry	3,200	3,400	40,600	8,800	6,100	5,200	9,000	7,100	5,600	5,100
Cork elm, green	4,500	4,900	57,700	12,400	8,700	7,500	12,800	10,100	8,000	7,300
Cork elm, air-dry	3,700	4,000	48,100	10,400	7,200	6,100	10,700	8,400	6,700	6,000

STRUCTURE OF THE WOOD.

Elm belongs to the group of ring porous woods, the beginning of each ring or layer of growth containing a band of more or less conspicuous pores. Throughout the rest of the growth ring there are smaller pores arranged in more or less continuous wavy lines. These wavy lines are of assistance in distinguishing elm from other ring porous woods, such as the hickories, ashes, oaks, and chestnut. The medullary rays are narrow and not visible to the unaided eye. In hackberry and sugarberry, which resemble the elms in structure, the rays are visible. The number, size, and arrangement of large and small pores serve to distinguish the wood of the different species. Slippery elm (Pl. I) has several rows of large pores, and the small pores are in somewhat interrupted wavy lines. In the other species of elm there is a single row of pores at the beginning of each annual ring. In cork elm (Pl. II) these pores are much smaller than in slippery and white elm (Pl. III), and the small pores are in very distinct, fairly continuous, wavy bands.

The following key may be used to distinguish the three principal elm species.[1] The characteristics mentioned may be seen on a smoothly cut cross section. A hand lens is an efficient aid in applying the key.

Pores of late wood arranged tangentially in conspicuous wavy, usually continuous, bands, the pores minute.

A. Rays very distinct to the unaided eye; heartwood indistinct, color yellowish.
HACKBERRY, *Celtis occidentalis.*
SUGARBERRY, *Celtis mississippiensis.*

B. Rays barely visible to the unaided eye; heartwood distinct, color reddish brown.
  1. Pores of early wood in a band 3 or more pores wide.
RED OR SLIPPERY ELM, *Ulmus pubescens.*

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[1] Wing elm is similar in appearance to cork elm, except that the bands of small pores are about as wide as the intervening spaces. Cedar elm may be distinguished by the very indistinct row of pores at the beginning of the annual ring.

2. Pores of early wood in a single tangential row.
    a. Pores of early wood comparatively large, forming a continuous row; bands of small pores numerous, usually about as wide as the intervening bands of dense tissue. Wood moderately hard and heavy. WHITE ELM, *Ulmus americana.*
    b. Pores of early wood minute, individual pores scarcely visible to the unaided eye, often rather widely separated; bands of small pores not so numerous as in white elm, narrower than the intervening bands of dense tissue (except in narrow rings). Wood very hard, heavy, dense........................CORK OR ROCK ELM, *Ulmus racemosa.*

SUPPLY AND DEMAND.

RANGE AND SIZE OF SPECIES.

The botanical range of white elm includes nearly all of the region east of the Rocky Mountains (fig. 1). The area of principal commercial importance, however, is southern New England, the Great Lakes States, and the southern Mississippi Valley. White elm is the largest of the elms, frequently attaining a height of from 100 to 120 feet, with a buttressed trunk from 6 to 10 feet in diameter. The range of slippery elm (fig. 2) is nearly as great as that of white elm and includes practically the same territory. Slippery elm is not

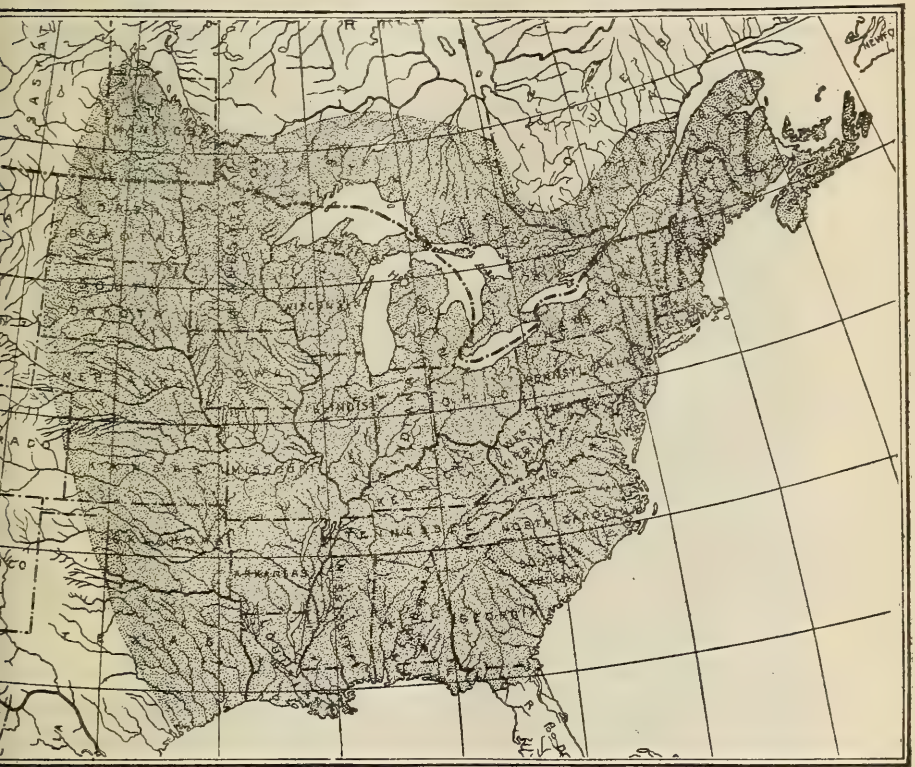


FIG. 1.—Distribution of white elm (*Ulmus americana*).

abundant, however, in any part of its range; the trees are scattered throughout the forest and the average size is small. The slippery elm tree grows to a height of from 60 to 70 feet, with a trunk rarely more than 2 to 2½ feet in diameter. The range of cork elm is much more limited than that of white and slippery elm (fig. 3). It does not extend farther south than Tennessee, and throughout a large part of the region of its distribution it is not important commercially. The tree attains a height of from 80 to 100 feet and a trunk diameter of from 3 to 4 feet. Wing elm grows in southeastern United States (fig. 4). It is commercially important in the western part of its range, chiefly in Missouri, Arkansas, and southeastern Texas. It rarely has a greater height than 60 feet or greater trunk diameter than 2 feet. Cedar elm occurs from southern Arkansas to Mississippi and in Texas. It reaches its best development in southern Arkansas and northeastern Texas, where it grows to a maximum height of 90 feet and a maximum trunk diameter of about 3 feet. It is fairly abundant in some localities in Texas.

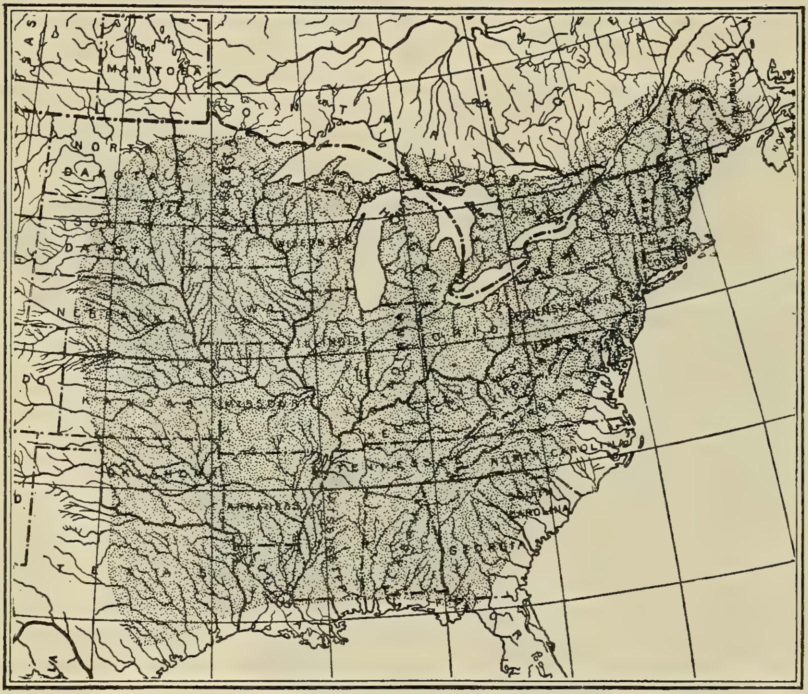
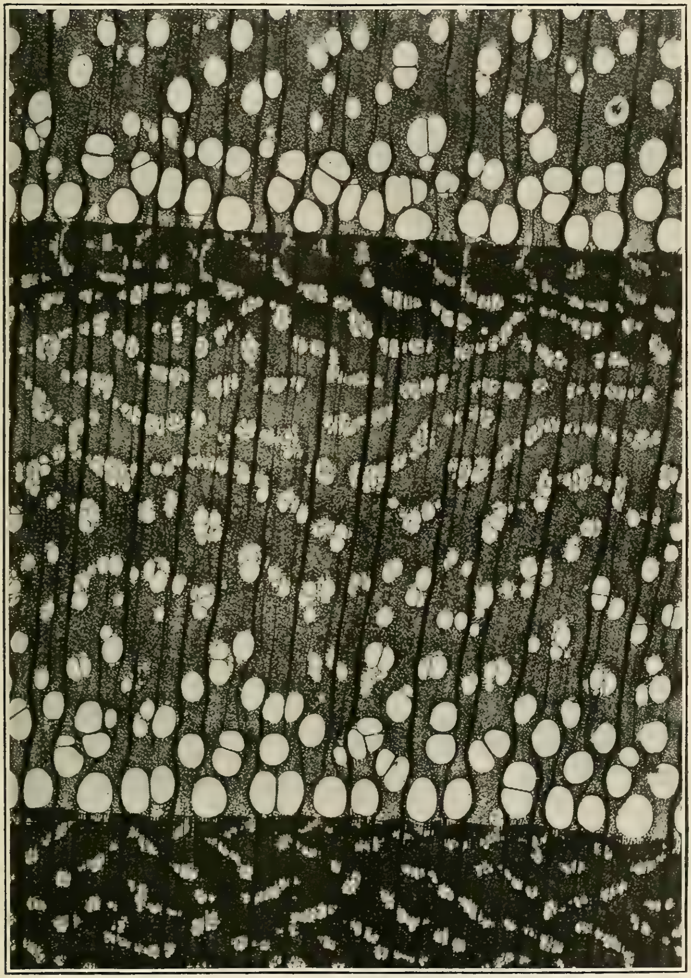


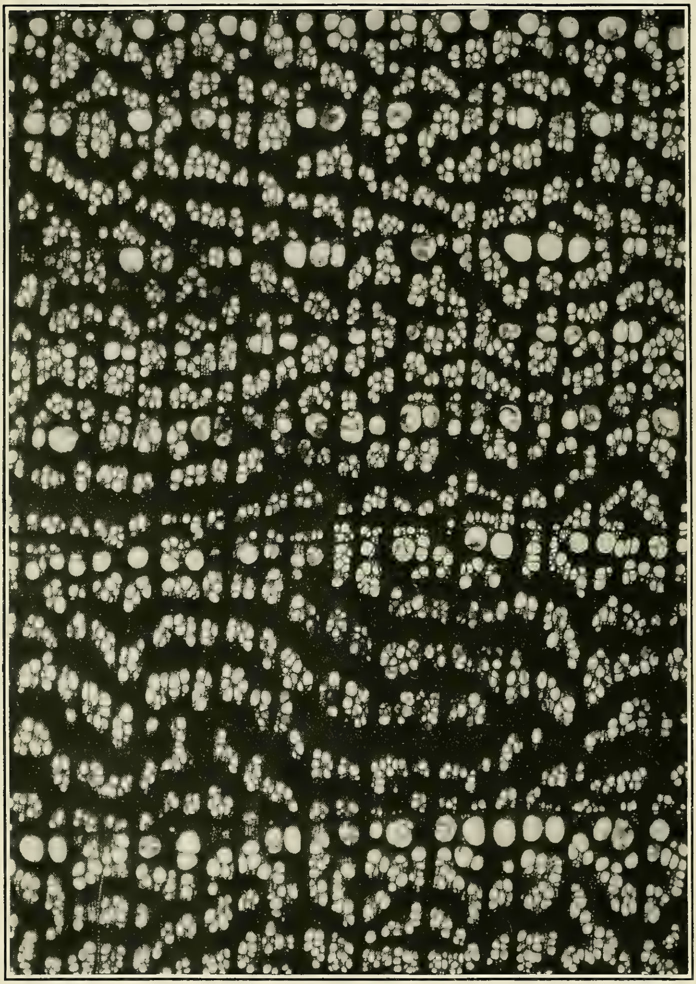
FIG. 2.—Distribution of slippery elm (*Ulmus fulva*).

SUPPLY.

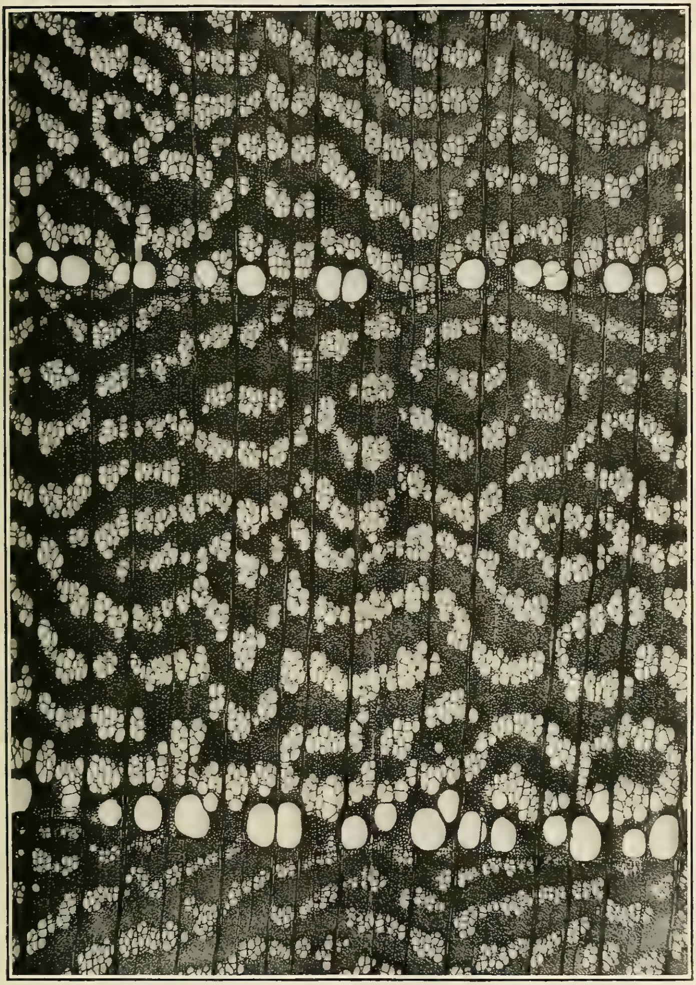
The principal supply of elm has come from the States bordering on the Great Lakes, but logging and agriculture have greatly reduced the stand. Wisconsin and Michigan still furnish a large supply of



TRANSVERSE SECTION OF THE WOOD OF SLIPPERY ELM; MAGNIFIED 20 DIAMETERS.



TRANSVERSE SECTION OF THE WOOD OF CORK ELM; MAGNIFIED 20 DIAMETERS.



TRANSVERSE SECTION OF THE WOOD OF WHITE ELM; MAGNIFIED 20 DIAMETERS.

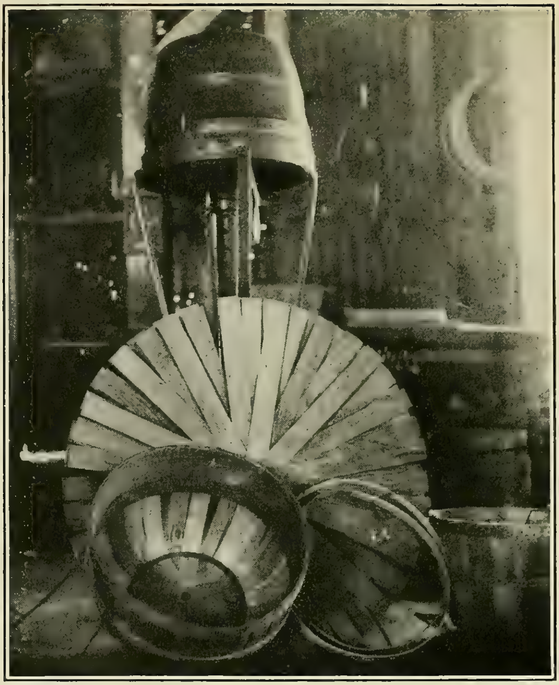


FIG. 1.—SHOWING MACHINE FOR MAKING BUSHEL BASKETS, SPLINTS IN CIRCULAR FORM READY FOR BENDING ON MACHINE, HOOP AND FINISHED BASKETS. GRAIN BASKET IN FRONT.

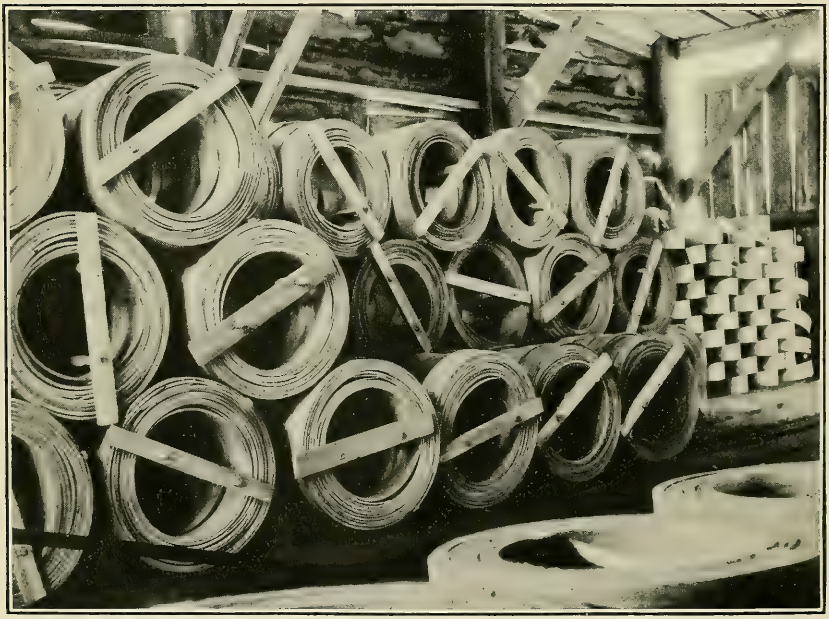


FIG. 2.—ELM RIMS USED FOR CHEESE BOXES AND ROUND MEASURES, READY FOR SHIPMENT.

the three important species. There is yet considerable standing timber of white elm in these two States, and one of the principal sources of supply is the northern third of the southern peninsula of Michigan. A large part of the total supply of cork elm also comes from the southern parts of Wisconsin and Michigan. This species of elm is being exhausted much more rapidly than the others.

So much of the forest timber has been removed in the Great Lakes region that factories requiring a large supply of cheap elm timber have in many cases been forced to discontinue operations there. Future supplies in this region must come largely from woodlots and small timber holdings.

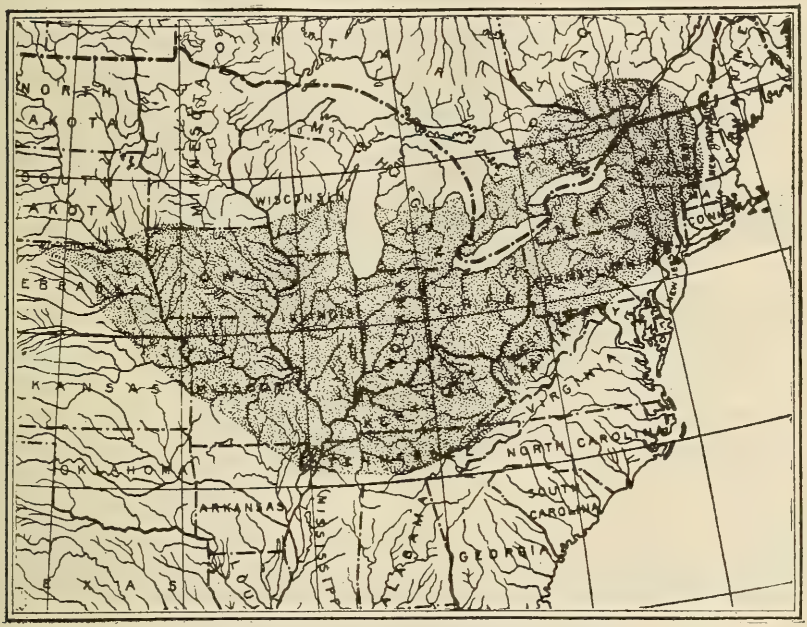


FIG. 3.—Distribution of cork elm (*Ulmus racemosa*).

There is considerable standing white elm in the southern Mississippi Valley region, where it has only recently been exploited to any great extent. Arkansas is now one of the principal sources of white-elm timber, but factories in that State which demand large quantities of elm in the log are already complaining that they have considerable trouble in securing a sufficient supply. Many of such factories have removed farther south to Mississippi and Louisiana. These two States have been yielding increasing amounts of elm saw timber each year and must be depended on for a large part of such timber in the future as well as a supply in log form for elm-using factories.

The elm timber of the southern Mississippi Valley region, in general, seems to differ in quality from that obtained in the Great

Lakes region. The southern elm is darker, usually reddish, and often variable in color, in contrast to the more uniform and lighter-colored northern elm. The darker and more variable color is not sought in the manufacture of some products, such as high-grade baskets, in which a white, clean appearance is desired. The southern elm also seems to be more defective, so that there is greater waste in manufacture. It has the reputation of being more brash and less strong than the northern elm, although probably considerable variation in these qualities would be found in material from any one region.

The stand of privately owned elm timber in Michigan, Wisconsin, and Minnesota was estimated by the Bureau of Corporations in 1907 to 1909 [1] to be 3,700,000,000 [2] board feet. These three States yield nearly one-half the elm saw timber produced in the United States. Assuming that the annual cut throughout the country is in proportion to the stand, it follows that there is a total stand of approximately seven and one-half billion feet. This would furnish a supply for approximately 30 years at the present rate of cutting. This does not take into account the manufacture of products other than elm lumber, such as slack cooperage, which are made directly from the log. Economic conditions in manufacture change so largely from year to year that any estimate regarding the probable exhaustion of the supply is unsafe. It is estimated that about three-fourths of the

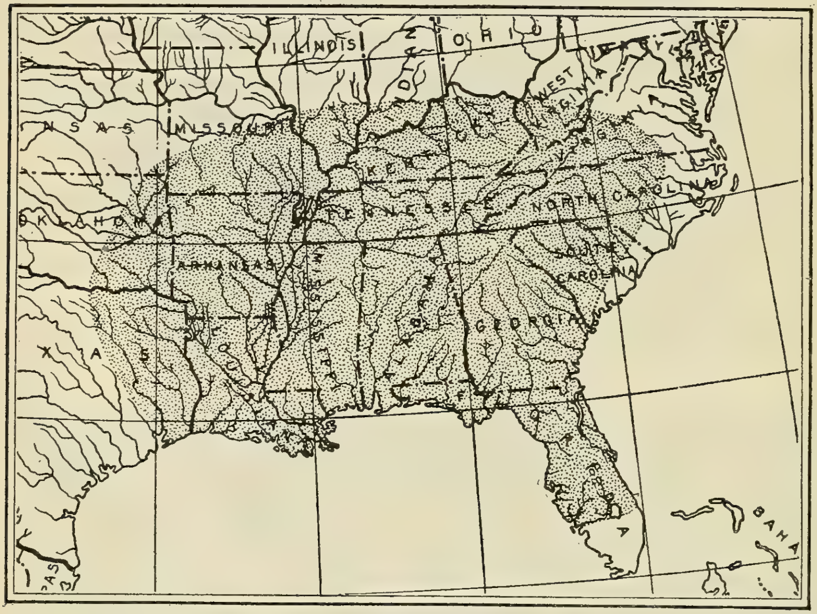


FIG. 4.—Distribution of wing elm (*Ulmus alata*).

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[1] Report on the Lumber Industry, Part I, Standing Timber, 1913, page 78.

[2] Michigan, 2,100,000,000; Wisconsin, 1,500,000,000; Minnesota, 100,000,000.

total amount of elm used is white elm, and it is probable that the proportion of the stand does not differ greatly from this figure. This would place the stand of white elm at about five and one-half billion feet.

No estimate can be made of the stand of slippery elm. It is cut in the same region as white elm. The trees are scattered throughout the forest, and the lumber is manufactured and placed on the market mixed with white elm. The stand of cork elm is likewise unknown. On account of its limited distribution and the heavy demand upon the supply it is rapidly diminishing.

The supply of wing elm and cedar elm is small, and these species are of commercial importance only in small restricted areas. Wing elm is evidently fairly abundant in certain locations, since an annual use of approximately a million feet has been reported in Texas, and probably more than that is used in each of the States of Missouri, Arkansas, Mississippi, and Louisiana. The stand of cedar elm is even less than that of wing elm, and it is used for local manufacturing purposes only. The wing and cedar elm trees are not usually larger in diameter than 2 feet, and the cedar elm is inclined to become shrubby in situations unfavorable for its growth.

LUMBER CUT.

The present output of elm lumber is about 240,000,000 board feet annually. This puts elm twentieth in rank among all woods and tenth among hardwoods in point of lumber production.

For the past 10 years elm has constituted between 3 and 3½ per cent of the total amount of hardwood lumber manufactured in the United States and between 1 and 2 per cent of the total of all woods. The amount of lumber cut does not represent the entire amount of wood used, since many woods are utilized by different industries largely in the form of the log or billet, and the amount so used is not reported as lumber. This is true to a certain extent of elm. Table 4 gives the production of elm lumber for different years by States. According to these figures, the production of elm lumber is decreasing rapidly. Nearly 347½ million feet were reported in 1909, about 262 million feet in 1912, and a little less than 178 million feet in 1915. However, there has not been a reduction in cut to the extent indicated by these figures, since the returns for years subsequent to 1909 are incomplete. This is shown by the computed total cut for 1916 of 240,000,000 feet. Table 5 shows the number of mills reporting elm for different years. Wisconsin and Michigan have been the leading States in the production of elm lumber for the last decade. There has been a decided decrease in production in New York, Ohio, Indiana, Illinois, Iowa, and Missouri. Arkansas, Louisiana, and Mississippi, on the other hand, have been producing increasing amounts. In Kentucky and Tennessee the production has been rather constant.

TABLE 4.—*Output of elm lumber, by States, in 1899 and from 1904 to 1915, inclusive, average value of the product f. o. b. mills, and number of mills reporting.*

State.	1899	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915
Total number of mills reporting	31,833	[1] 18,277	11,666	22,398	28,850	31,231	[2] 46,584	[1] 31,934	[1] 28,107	[1] 29,005	[1] 21,668	[1] 27,506	[1] 16,815
Total number of mills cutting elm	....	....	1,937	....	[3] 3,400	[3] 4,771	8,028	5,785	5,159	5,573	3,034	2,665	2,730
Average value per 1,000 board feet f. o. b. mill.	$11.47	$14.45	....	$18.08	$18.45	$18.40	$17.52	$18.67	$17.13	$16.87	....	....	$16.98
	1,000 bd. ft.	*1,000 bd. ft.*	*1,000 bd. ft.*	*1,000 bd. ft.*	*1,000 bd. ft.*	*1,000 bd. ft.*	*1,000 bd. ft.*	*1,000 bd. ft.*	*1,000 bd. ft.*	*1,000 bd. ft.*	*1,000 bd. ft.*	*1,000 bd. ft.*	*1,000 bd. ft.*
Total cut of elm	456,731	258,330	227,038	224,795	260,579	273,845	347,456	265,107	236,108	262,141	214,532	214,294	[4] 177,748
Wisconsin	76,897	52,895	70,327	42,136	57,397	63,425	75,472	68,037	55,193	50,608	52,307	51,640	42,534
Michigan	109,443	78,255	57,305	29,261	33,797	48,441	58,321	53,050	47,991	52,757	45,415	41,790	35,598
Arkansas	3,228	15,876	9,321	11,532	11,925	8,237	13,056	11,470	12,228	13,172	11,815	16,141	17,055
Indiana	74,669	40,503	24,911	34,580	37,984	25,740	40,364	25,872	19,974	27,463	20,624	22,507	15,129
Ohio	93,413	27,089	22,464	29,058	27,970	27,100	33,182	24,199	25,927	28,968	19,345	14,411	13,815
New York	16,157	4,611	7,425	19,855	25,427	26,609	16,280	10,112	12,462	13,684	11,016	12,776	9,435
Missouri	28,124	9,345	8,425	15,251	17,215	18,695	27,913	19,043	15,318	22,279	13,648	16,738	8,817
Tennessee	3,493	3,043	3,369	4,513	5,727	9,477	10,688	7,225	6,108	6,176	9,219	13,764	7,825
Louisiana	83	....	7	302	696	308	1,341	1,703	1,791	2,100	2,860	3,752	6,031
Mississippi	....	1,030	2,037	3,703	2,692	4,808	6,090	7,356	3,636	5,759	6,750	4,646	4,857
Minnesota	8,354	2,652	5,251	2,555	6,192	8,956	14,645	9,738	9,833	12,245	5,752	4,259	3,754
Illinois	16,667	8,778	7,584	12,699	12,585	11,419	12,102	6,549	5,097	6,874	3,656	5,375	2,780
Kentucky	3,213	3,456	2,351	3,994	5,277	4,939	10,130	4,551	3,264	3,797	3,760	1,178	2,358
Iowa	13,873	2,516	1,503	4,234	4,158	4,955	11,710	6,648	6,309	4,981	3,263	646	2,161
Pennsylvania	2,619	5,754	2,323	5,635	5,796	2,867	4,954	2,224	3,192	2,994	830	1,188	1,155
Vermont	628	1,442	947	1,759	1,387	1,341	1,766	1,489	1,575	1,348	483	568	1,003
Maine	68	....	421	623	513	701	910	554	599	407	85	106	517
Texas	2,018	....	47	20	478	694	703	431	588	852	792	450	513
Oklahoma	230	60	140	141	1,043	2,592	2,140	1,777	1,776	1,304	363	681	434
North Carolina	....	....	52	187	70	75	404	164	53	52	760	10	314
West Virginia	....	255	116	508	458	481	881	546	325	165	488	43	291
Georgia	....	35	110	144	93	354	274	330	212	203	306	422	271
Alabama	568	....	32	429	156	284	1,082	536	664	2,217	179	571	247
New Jersey	22	50	160	94	102	48	102	138	150	70	35	45	244
South Carolina	....	....	17	51	8	21	19	168	140	186	422	306	234
Virginia	2	....	20	426	151	105	244	138	223	163	22	75	148
Connecticut	3	....	107	521	257	306	367	215	192	152	47	45	69
Massachusetts	....	....	72	322	281	395	366	200	295	262	56	58	67
New Hampshire	....	....	50	290	447	286	242	385	844	350	8	35	54
Maryland	....	....	61	58	190	105	974	87	32	177	35	36	38
Rhode Island	....	....	....	74	57	6	6	10	5	15	....	....	....
Florida	....	....	3	....	....	....	5	....	....	20	....	....	....
Delaware	....	....	....	....	....	....	3	5	....	....	....	5	....
Utah	....	....	....	....	....	....	....	....	22	....	....	....	....
South Dakota	....	....	....	....	....	....	....	....	5	....	....	....	....
All other States (Kansas and Nebraska)	2,959	745	80	40	50	75	720	157	85	341	191	35	....

[1] Mills cutting under 50,000 feet excluded.

[2] Includes 4,543 mills cutting less than 50,000 feet, and all cooperage, veneer, millwork, box, furniture, and other factories cutting any lumber in 1909.

[3] Not including New York.

[4] Computed total production 210,000,000.

TABLE 5.—*Number of mills reporting lumber cut of elm in the different States.*

State.	1905	1907	1908	1909	1910	1911	1912	1913	1914	1915
Total	1,937	[1] 3,400	[1] 4,771	8,028	5,785	5,159	5,573	3,034	2,665	2,730
Wisconsin	254	199	569	680	545	492	502	315	265	264
Michigan	254	175	504	700	567	515	488	305	208	217
Arkansas	54	136	107	220	126	100	119	69	68	72
Indiana	299	605	666	914	648	537	597	307	329	293
Ohio	316	520	620	920	650	575	703	322	301	319
New York	......	(2)	(2)	850	605	696	684	758	640	570
Missouri	72	283	388	810	527	445	462	243	175	135
Tennessee	......	161	236	400	293	220	268	124	169	116
Louisiana	......	*a*	11	28	21	18	24	22	30	26
Mississippi	......	*a*	74	86	77	57	64	43	51	49
Minnesota	......	66	195	298	236	211	222	35	61	60
Illinois	......	296	320	436	281	231	284	126	86	63
Kentucky	......	212	245	395	286	218	252	93	33	79
Iowa	......	*a*	89	282	146	137	131	82	21	64
Pennsylvania	......	221	236	308	204	197	233	48	78	119
Vermont	......	*a*	119	134	130	125	130	34	43	77
Maine	......	*a*	78	80	64	60	60	13	10	53
Texas	......	*a*	10	21	13	18	23	9	7	9
Oklahoma	......	*a*	64	88	71	60	60	16	20	17
North Carolina	......	*a*	2	23	12	8	9	11	1	8
West Virginia	......	*a*	34	61	46	36	36	9	10	21
Georgia	......	*a*	19	15	17	10	20	5	4	8
Alabama	......	*a*	17	45	40	25	27	6	16	15
New Jersey	......	*a*	13	17	19	16	16	4	2	15
South Carolina	......	*a*	3	5	4	7	5	4	5	3
Virginia	......	*a*	7	31	20	11	16	5	1	11
Connecticut	......	*a*	30	38	34	41	33	7	11	17
Massachusetts	......	*a*	46	56	41	34	40	8	8	11
New Hampshire	......	*a*	47	42	38	42	39	4	5	13
Maryland	......	*a*	17	38	16	10	15	2	2	6
Rhode Island	......	*a*	2	2	1	1	1	......	......	......
Florida	......	......	......	1	......	......	......	......	......	......
Delaware	......	......	......	1	1	......	......	......	1	......
Utah	......	......	......	......	......	1	......	......	......	......
South Dakota	......	......	......	......	......	1	......	......	......	......
Kansas and Nebraska	......	*a*	3	3	6	4	9	5	4	......
All others	[3] 688	[4] 526	......	......	......	......	......	......	......	......

[1] New York not included.

[2] No report.

[3] Including 26 other States.

[4] Including those marked "*a*".

AMOUNT CONSUMED.

Since little elm is used in the rough for building construction, ties, poles, etc., practically all of the elm timber cut (except that used for fuel) eventually reaches the factory, in the form either of logs or lumber, to be manufactured into various products. The annual demand for elm by factories in the United States, according to the most recent statistics, amounts to about 365,000,000 feet board measure, including all forms of raw material. This figure applies more particularly to the year 1911. There has probably been some diminution in the amount used since that time on account of the waning supply. Considerable elm wood is used for fuel each year, but no estimates are available.

Table 6 shows the amount of elm used in the factories of each State. The States bordering the Great Lakes, also Missouri and Arkansas, use the largest amounts. Kentucky, Tennessee, Mississippi, and Louisiana use considerable elm. A comparison of Tables 4 and 6 shows that in general those States leading in lumber production also lead in amounts used by factories, indicating that industries using elm do not generally get their raw material at any great distance. In the case of Pennsylvania, however, where the lumber cut of elm is small, manufacturers reported that 90 per cent was secured from outside the State. In Illinois at least 70 per cent came from outside, mostly from Michigan and Wisconsin. In New York 50 per cent of the raw material was not native to the State. In such States as Ohio, Indiana, and Missouri, where the lumber cut has decreased considerably in the past few years, the use of elm by factories is no doubt much less at the present time than is indicated in the table. In Arkansas, Mississippi, and Louisiana, on the other hand, the amounts consumed have doubtless increased recently. Many factories of Michigan and Wisconsin, especially hoop and basket factories which use material in the log, have moved to the lower Mississippi Valley during the past few years to get a sufficient elm supply.

TABLE 6.—*Annual consumption of elm in factories, by States.*

State.	Feet B. M.	State.	Feet B. M.
Michigan	79,105,951	Maryland	592,000
Ohio	59,229,054	Alabama	570,000
Wisconsin	42,193,400	Vermont	569,625
Illinois	38,308,000	Virginia	445,581
Indiana	34,578,723	West Virginia	204,000
Arkansas	22,567,000	North Carolina	197,000
New York	19,237,500	Nebraska	130,581
Missouri	19,176,103	Maine	115,500
Pennsylvania	10,415,843	Oklahoma	110,000
Tennessee	8,347,000	Kansas	107,000
Louisiana	6,858,000	South Carolina	100,000
Iowa	4,832,527	Washington	100,000
Minnesota	3,549,001	Delaware	56,246
Mississippi	3,080,000	California	40,000
Kentucky	3,059,000	Georgia	38,000
Massachusetts	2,706,000	Oregon	10,200
Texas	1,866,000	Rhode Island	4,000
Connecticut	1,295,900	Montana	1,500
New Hampshire	704,273		
New Jersey	654,440	Total	365,154,988

UTILIZATION BY INDUSTRIES.

Table 7 gives the annual factory consumption of elm grouped according to industries. These figures show that the slack cooperage industry is by far the most important, the amount credited to this use being more than twice that of the next in importance, baskets and crates. The figure for slack cooperage was obtained by converting to board feet census figures on the total amount of slack cooperage stock manufactured, while figures for other industries are in terms of amounts of lumber consumed. There is a large amount of waste in the slack cooperage industry, so that without doubt more than 147,000,000 board feet of lumber could have been produced from the same raw material which was used in the manufacture of this amount of slack-cooperage stock. The importance of this industry, therefore, is probably somewhat greater than is shown in the table. Figures for slack cooperage are those compiled by the

Bureau of the Census for the year 1911. Statistics for other industries were collected by the Office of Industrial Investigations of the Forest Service during the years 1909 to 1913. The figures given, therefore, must be taken only in a general way as representing the situation in elm utilization, since conditions change somewhat from year to year.

TABLE 7.—*Annual consumption of elm in factories in the United States, by industries.*

Industry.	Feet B. M.	Per cent.
Slack cooperage	[1] 146,954,000	39.63
Boxes, baskets, and crates	65,535,458	18.13
Vehicles and vehicle parts	31,296,922	8.66
Chairs and chair stock	23,157,586	....
Woodenware and dairymen's and poulterers' supplies	16,383,426	4.53
Musical instruments	15,602,440	4.32
Refrigerators and kitchen cabinets	13,046,100	....
Furniture	12,154,102	....
Agricultural implements	7,249,000	2.01
Trunks and valises	6,409,286	1.77
Fixtures	6,368,275	....
Planing mill products, sash and doors	6,218,860	1.72
Sporting and athletic goods	3,226,750	.89
Handles	3,060,307	.85
Toys	2,042,055	.56
Laundry appliances	1,365,000	.38
Car construction	1,221,121	.34
Machine construction	831,000	.23
Ship and boat building	706,600	.20
Machinery and apparatus, electrical	463,000	.13
Equipment, playground	334,000	.09
Saddles and harness	276,000	.08
Pulleys and conveyors	200,000	.06
Signs and supplies	200,000	.06
Brushes	187,000	.05
Dowels	175,000	.05
Gates and fencing	155,000	.04
Printing material	84,200	.02
Elevators	68,500	.02
Plumbers' woodwork	55,000	.01
Frames and moulding, picture	43,000	.01
Patterns and flasks	40,000	.01
Pumps and wood pipe	20,000	.01
Tanks and silos	15,000	(2)
Mine equipment	8,800	(2)
Boot and shoe findings	2,000	(2)
Instruments, professional and scientific	200	(2)
Total	365,154,988	100.00

[1] Amount of product reduced to board feet. From Bureau of the Census statistics on slack cooperage, which also includes small buckets, pails, and tubs. Since these articles are also included in woodenware in the table, there is probably some duplication in figures for these two industries.

[2] Less than one-half of 1/100 per cent.

Elm enters into the manufacture of a large number of products made from wood; in fact, there are probably few industries which do not furnish a demand for more or less of it.

For most uses to which elm is put the different elm species are used indiscriminately. For certain uses, however, some one species is preferred, as cork elm on account of its extreme hardness. On pages 39 to 43 is given a list of uses reported for the different species and for elm without reference to species.

Reports received from manufacturers give an average cost of $23.55 per 1,000 board feet for elm, not including the slack-cooperage industry.[1]

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[1] The prices given for elm products are those in effect before the entrance of the United States into the war.

SLACK COOPERAGE.

Elm is one of the most important slack-cooperage woods of this country, being well adapted for slack barrels on account of its strength and ability to stand rough usage.

The amount of elm slack-cooperage stock manufactured in 1911, reduced to board feet, was as follows: 111,099,000 board feet of hoops, 30,871,000 board feet of staves, and 4,984,000 board feet of heading. Statistics showing the amount of elm consumed in the manufacture of this stock are not available.

Slack-cooperage statistics for the years 1907 to 1911 show that elm is by far the most used wood for hoops. In 1911 about 94 per cent of the wooden hoops produced (over 333,000,000) were of elm. The figures for 1907 to 1911 show in general a decline in the use of elm for this purpose, which is explained in part at least by the use of metal hoops.

The usual method of manufacturing elm hoops for slack cooperage stock is as follows: The logs are first cut into flitches $1\frac{9}{16}$ inches thick, and as long as the hoops to be cut from them. These flitches are then steamed; and the hoops, five-sixteenths inch thick on one edge and three-sixteenths inch thick on the other edge, are sliced lengthwise from them. The edges are next rounded, the width of the hoop being reduced in the process to $1\frac{1}{2}$ inches. The hoops are steamed, and then coiled—usually 10 or 12 are coiled together in a bundle.

The cost of manufacturing hoops in the lower Mississippi Valley region averages about $6.50 or $7 per thousand hoops. It may run as high as $7.50 per thousand or higher, depending largely on the cost of the logs. Water transportation is as a rule cheaper than rail, and slack-cooperage manufacturers located on the Mississippi River can usually secure rafted timber at a comparatively low figure. Manufacturers who buy stumpage and do their own logging also have the advantage of low cost of raw material.

Hoop makers use more of the white elm than of the other kinds. Some red elm and a little cork elm are used, but the latter is not well liked because it is difficult to work with tools. Elm grown in moist situations is more porous and bends better than that grown on higher and drier locations and for this reason is better liked by the hoop maker. On the other hand, much of the swamp-grown elm of the South is more brash than the northern elm. It is also very defective, so that there is more waste in manufacturing hoops from it than from elm grown in the North.

In 1906 elm was more largely used for staves than any other wood; in 1907 and 1908 it took third place; and in 1909, 1910, and 1911 it ranked fourth and was preceded by red gum, pine, and beech. The per cent of decrease for 1911 as compared with 1910 was greater than for any other important wood in stave manufacture. About 7 per cent (92,614,000) of the total number of staves reported for 1911 were of elm. The output of elm staves is therefore being replaced by other woods, which is due to a depletion of the supply in the regions of stave manufacture.

Woods which steam well and retain their form when bent, and which do not taint or sour substances in contact with them, make the choicest stave material. Elm fills these requirements to a high degree, and on account of its additional advantage of great strength is generally considered the most desirable wood for slack-barrel staves.

Good quality elm staves are much in demand for the highest grade slack barrel, principally for sugar and flour. Elm is well liked for sugar barrels on account of its strength. Lower grade elm staves serve well in barrels used for shipping bottles, glassware, crockery, etc. A good grade of elm staves often brings a high price. A high grade of No. 1 for sugar and flour barrels may sell for from $9.50 to $10 a thousand. The usual price, however, is about $9. Red gum has largely replaced elm as a stave wood on account of the growing scarcity of the latter wood and the plentifulness of gum in the regions where slack stave factories are now operating. Although not as strong as elm it makes a satisfactory stave. No. 1 gum staves usually bring about $8 a thousand. Some manufacturers are unable to get more than 50 cents a thousand for elm staves above the price for gum and find it more profitable to manufacture the best of their elm into lumber, converting the more defective material into low-grade staves. Hackberry is sometimes used in place of elm. Hackberry, however, is not so strong. It is also not durable, and logs often decay badly before going into the factory.

Elm is not so much in demand for heading, because it is likely to warp when exposed to alternate wet and dry conditions. Less than 2½ per cent of the total amount of slack heading reported in 1911 was of this wood. Elm is used for head linings, which are thin strips used to hold the heading in place.

Elm is manufactured into slack-cooperage stock principally in the States bordering the Great Lakes, and in Mississippi, Arkansas, and Tennessee. In 1911 Ohio stood first in the production of hoops, Indiana second, and Michigan third. For many years the hoop industry was confined to these three States by reason of the abundance and excellent quality of the elm growing there. In 1907 they manufactured 86.4 per cent of the output and in 1908, 82.4 per cent, but in 1911 their production fell to 64.9 per cent. The hoop industry is moving southward. In 1911 Arkansas was fourth, Mississippi fifth, and Louisiana sixth in importance in the manufacture of hoops. Mississippi has shown a great increase in hoop manufacture, holding ninth place in 1911. Hoop factories of Ohio and Indiana have been forced to go elsewhere for a supply of elm. Hoop makers in Michigan have in many cases moved to the lower Mississippi Valley on account of the growing shortage in the Great Lakes region. Memphis has of late years become the principal center of elm-hoop manufacture, a large number of factories being located within a radius of 100 miles of that city. Recently, many factories have gone farther south for fresh supplies, since the hoop maker demands a large supply of the best timber. The hoop industry will doubtless be located for some time to come chiefly in Mississippi and Louisiana.

Over one-fourth of the total amount of elm staves reported for 1911 were from Michigan. Missouri and Arkansas came next in importance. These three States produced over 60 per cent of the total amount.

Arkansas and Michigan led in the production of heading in 1911, including all woods. Woods other than elm, however, were chiefly instrumental in giving these States first place in the manufacture of this product.

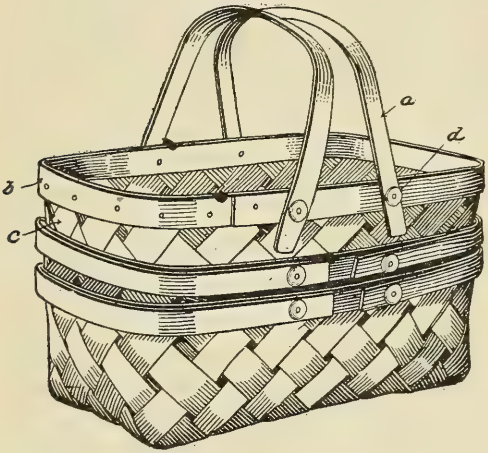

FIG. 5.—Market baskets with elm rims and handles. *a*, Elm handle; *b*, elm rims—one outside, one inside; *c*, splints; *d*, metal washer.

BOXES, BASKETS, AND CRATES.

One of the most important uses of elm is in the manufacture of baskets, including fruit and vegetable packages of various kinds. Elm is used principally for the outside and inside bands or rims, on account of its strength and good bending properties. In the ordinary market basket (fig. 5) the outside and inside bands at the top and also the bent handles are preferably of elm. Two straps of elm on the bottom outside the basket make it much stronger and protect the bottom. Elm is in great demand for the bushel and half-bushel baskets (fig. 6), for the outside and inside bands and for the bale, if they have one. Enormous quantities of these baskets, used principally for shipping fruit and vegetables, are made by special machines. A special form of this type is the grain basket (Pl. IV, fig. 1), which has a wide band of elm on the inside at the top and is a strong, tight basket. Its serviceability is further increased by a round bottom of elm often both outside and inside; or a circular rim of elm may be placed on the bottom to protect it from injury. Occasionally the staves are of elm, which makes the most serviceable basket.[1]

Basket makers generally get their wood locally in the log, or they may secure the rims from a hoop factory. It is not profitable for them to ship the raw material in any large amounts from a distance.

One of the most common uses of elm is for all kinds of crating. It can be cut into thin material and in this form can be used in long pieces. Thin elm boards 10 feet or more in length may be bent to a circle without breaking. It is therefore adapted for crating such merchandise as furniture and machinery. Crating is usually made from low-grade lumber. Factories which manufacture vehicles and furniture may buy low-grade elm and make crating from it; or they may buy log run and use the upper grades in the manufacture of their products. Manufacturers of Michigan and Wisconsin usually buy No. 3 common and cull for crating, for which they pay an average price of about $14 per thousand.

Fruit and vegetable crates of rectangular form are often made of elm. Eggs and butter are occasionally packed in elm crates. Elm wood is said not to be altogether suitable for this purpose, however, because a slight taste is imparted to these products.

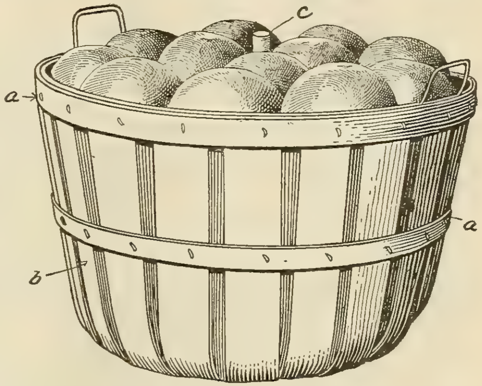

Fig. 6.—Bushel shipping basket with elm rims. *a*, Rims; *b*, splints or staves; *c*, center post which keeps fruit from being crushed. Cover not shown.

Small fancy boxes are often made of white elm and nicely finished to imitate other woods. This is particularly true of tobacco boxes, for which the elm is finished in imitation of Spanish cedar. The best grade of elm is usually obtained and is less than half as expensive as the cedar. An annual consumption of nearly 2,000,000 board feet of elm was reported by manufacturers for this use alone.

Of the approximately 65,000,000 board feet of elm consumed annually for all kinds of baskets, boxes, and crating, it has been estimated that approximately 85 per cent is white elm, which is used in largest quantities in Michigan, New York, Illinois, Ohio, and Indiana.

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[1] For the staves of nearly all kinds of baskets more plentiful hardwoods, such as beech and maple, are used. Beech is sometimes used to a limited extent for rims in place of elm, but does not bend so well and is not so serviceable. Birch has been tried also with fairly good results. Bushel-basket rims are sometimes made of red gum. They are much inferior to elm rims, but can be made for about one-half the cost of the elm. Hackberry is used in place of elm and is considered just as good, but only a small supply can be obtained.

The estimate for slippery elm is 12 per cent, used mostly in Illinois and Indiana. Small amounts of cork elm are used in several northern States and a small amount of wing elm in Texas. Reports from manufacturers included under this head give an average cost of $18.63 at the factory for elm. This is a low price compared to the prices paid for elm by other industries, and is due to its being obtained largely in the log and also to the utilization of low-grade material.

VEHICLES.

Elm is an important vehicle wood, an annual use of more than 31,000,000 board feet being reported. Michigan, Ohio, and Wisconsin lead in its consumption for vehicles and vehicle stock, the amount reported for these States being as follows: Michigan, 7,813,000; Ohio, 7,285,000; Wisconsin, 6,657,000. The total for the three States is nearly 70 per cent that of the entire United States. Iowa, Arkansas, Indiana, and Minnesota are next in order, consuming amounts between approximately one and two million board feet.

About two-thirds of the total was reported as white or gray elm or simply as "elm," and about one-third as cork and rock elm, and a very small per cent as slippery elm. White elm is chiefly valuable for the frames of bodies and tops of vehicles. Cork elm is used for singletrees and eveners, and for parts of the running gear, such as reaches and hounds, especially of light vehicles, and for the bows on which the top is stretched.

There has always been a good demand for rock elm for wagon and carriage hubs because of its hardness and ability to stand shock. The hub is bored out and is either completely covered by steel bands or a band sunk into it on each side to prevent checking. On account of the growing popularity of the automobile, which has all metal hubs, the demand for this material is now comparatively small. Some large wheel manufacturers have a sufficient supply of elm hub material to last for several years.

In 1911 Michigan manufacturers reported an annual consumption of 842,000 feet for automobiles. Since then there has been a considerable increase in the quantity used for automobiles, and probably a decrease in the quantity for horse-drawn vehicles.

Both the white and cork elm are used by automobile body makers. The cork or "rock" elm is used for corner blocks in the framework because of its strength and its ability to withstand shock and to hold screws. Large quantities of white and slippery elm go into the framework, chiefly in bent pieces. The more porous elm (often called swamp and water elm) is preferred, since it is said not to break so readily in bending. The wood is received at the factory in the green condition, is steamed, then bent to the desired form, held in shape, and kiln dried. Even when great care is exercised to select proper material for bending, considerable difficulty is experienced from splintering and breaking because pieces as much as 2 inches square must be bent quite sharply at right angles. Figure 7 shows some of the common bent forms used. A good supply of satisfactory elm material is important to automobile body makers, for they consider that no other wood can replace it for the back rails, wheel housings (where thin material is bent in curved form), and other small bent pieces (fig. 8). Elm from southern Michigan is considered not so satisfactory for these uses as that from the northern part of the southern peninsula. That from the extreme southern States is considered inferior because of the presence of numerous defects. Material is secured mostly in the form of 1 and 2 inch lumber, and a large supply is usually kept on hand. Many automobile body makers report a purchase price of from $40 to $50 a thousand for various grades of white and rock elm. Thirty-eight dollars is the average price reported by a considerable number of such manufacturers, which

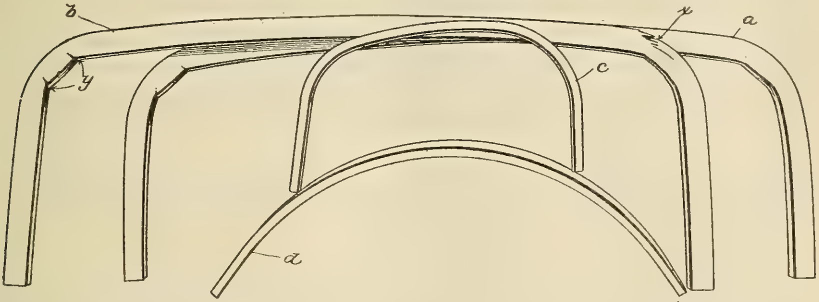

FIG. 7.—Some common forms of elm bent-wood pieces used in automobile bodies. The most exacting demands are made upon the wood by the forms *a* and *b*, used for back rails, on account of the sharpness of the bends. The two common modes of failure in bending are illustrated in *b*, which is a cull piece; in the right-hand bend at *x* splintering tension has taken place, and the left-hand bend shows compression failure at *y*, the fibers of the wood being folded over. The forms *c* and *d* are not so difficult to make, since the bends are more gradual.

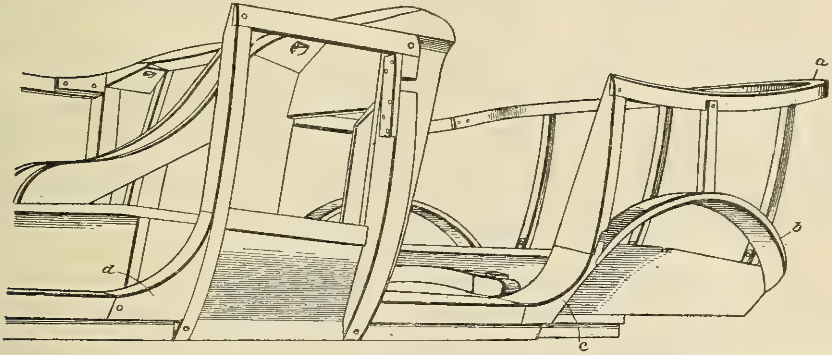

FIG. 8.—Partially assembled wooden framework of automobile body. The bent-wood piece (*a*) forming the back rail of the rear seat is soft elm, and also the circular piece (*b*), above where the wheel is to be located. The triangular blocks (*c* and *d*) to the right of each side door at the base are rock elm.

is nearly 50 per cent higher than the average cost reported for elm in the vehicle industry.

Elm is not in general use for spokes of ordinary vehicle wheels, since the wood is inclined to warp when it absorbs moisture and does not hold its shape as well as hickory. Both the cork elm and white elm are used, however, for the extremely long spokes of large wagon wheels such as are used in logging. Large log wheels as much as 9 feet in diameter are often fitted with cork-elm spokes, and it is said that no other wood has been found to be quite so satisfactory.

Cork elm is frequently used for the felloes, or bent rims, of light wagons and carriages and is said to be satisfactory as rims for bicycles in place of hickory. Cork elm serves as a substitute for hickory in many parts of light vehicles.

Cork elm is used in cutters and sleighs for the runners and running gear. White and cork elm are also used for other parts in place of ash and hickory. Elm is commonly used in the manufacture of wheelbarrows, for which it is well adapted because of its ability to stand shocks. It is used principally for the handles, for which the cork elm is most suitable. Factories generally utilize No. 2 common and better for this product.

An average cost of $26.71 per thousand board feet at the factory is reported for elm by vehicle manufacturers. This is above the average of elm for all industries, but is low for the vehicle industry. This is evidently due to the large proportion of white elm included for which a much lower price was paid than for the cork elm. For instance, in Michigan the average cost of white elm is reported as $23 a thousand and of cork elm $36. Vehicle makers demand a good grade of rock elm for such purposes as eveners, singletrees, and running gears.

No. 1 common and better 2 inches thick is generally used at a cost of from $35 to $40 a thousand feet. For cutters and sleighs, 1 and 2 inch lumber No. 2 common and better, both white and rock elm, is usually purchased at an average price of from $25 to $30.

CHAIRS AND CHAIR STOCK.

Elm is well adapted for chair making, as is shown by this industry's being fourth in importance in its use. It is used particularly for rockers, also for bent arms. It is, however, not so strong and tough as hickory, does not take so smooth a polish, and is more apt to splinter on the surface. The chair maker prefers the rock elm for most uses, but the soft elm is also used. The average price per thousand board feet paid for elm by this industry is $25.63. This is about $2 per thousand above the average for all industries.

WOODENWARE AND DAIRYMEN'S AND POULTERERS' SUPPLIES.

For such products as candy pails and tobacco buckets elm is desirable because it has very little odor and taste. It is also used for butter tubs.

Considerable elm is made into bent rims for the circular sides of such articles as cheese boxes and round measures. The raw material is generally secured in the log, slabbed, and cut into planks up to 4 inches thick, depending on the width of the rim to be cut from it. The planks are then steamed and sliced. The strips are next planed, steamed, put through rollers, and placed in a circular form which holds them in the desired shape until dry. Plate IV, fig. 2, shows rims for cheese boxes ready for shipment. In making these rims the softer grades of elm are used because of their ease in working. Cheese-box rims are also made from veneer cut directly from the log by the rotary process.[1]

Cork elm plays an important part in the manufacture of step-ladders, stepladder chairs, and stepladder stools. It is especially desirable for the top step of such ladders and for other pieces where there is considerable strain and the screws must hold very firmly and not work loose. Cork elm is a good wood for long ladders, especially for the rungs, where it is very serviceable. Tent pins and slides are made of rock elm because of its good wearing qualities.

An average price of $16.85 per thousand board feet is reported for elm used in woodenware and dairymen's and poulterers' supplies. This is about the lowest price recorded for any one industry using elm and is due to its being obtained in the log and from local sources for the manufacture of such products as bent rims. Many other articles included under this heading which take relatively small amounts pay a much higher price; rock-elm lumber for ladder rungs, for instance, usually costs the factories about $30 a thousand board feet.

MUSICAL INSTRUMENTS.

A large quantity of elm goes into pianos and organs, in which it is utilized largely for the framework. Its cheapness in comparison to other suitable woods, its strength, ability to stand shock, and good gluing qualities recommend it especially for this industry. It is not used so much now as formerly on account of its increasing scarcity. It was formerly considered as the most desirable wood for posts and backs of pianos, and considerable is still used for these parts.[2] A comparatively high price per thousand feet ($33.62) is reported for elm in this industry, since high-grade material is required.

REFRIGERATORS AND KITCHEN CABINETS.

Elm is much used for kitchen furniture, for which over 13,000,000 board feet are consumed annually. White elm is particularly adapted for kitchen cabinets and kitchen tables because it scours clean and white, is free from stain, taste, and odor, and has considerable stiffness and strength. It is a very desirable wood where frequent scrubbings are necessary. Elm has been employed to a considerable extent in the manufacture of refrigerators. It is not altogether satisfactory, however, because it warps in damp situations. Ash is much preferred, but often costs considerably more. An average price of $23.72 per thousand feet is paid for elm for these uses.

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[1] Red oak is also used for rims, but is not so satisfactory. Birch is a fairly good wood for cheese-box sides. Black ash is sometimes used, but is not so suitable. Red gum has been tried, but its brittleness is a decided drawback.

[2] Hard and soft maple veneer glued together in alternate layers with a sheet of hard maple on the outside to give an attractive appearance has largely displaced elm for piano backs. Posts of hard maple are also used.

FURNITURE.

Elm does not hold a place of first importance as a furniture wood; but it is useful for many purposes in the industry, which uses more than 12,000,000 board feet annually, exclusive of what goes into fixtures and chairs. Its place is in cheap furniture or the interior parts of more expensive kinds. Much of the elm used for furniture goes into the framework, on account of its strength and its ability to hold screws and stand shocks. It is used especially for the framework of upholstered furniture. In recent years it has been successfully finished to imitate birch, maple, and cherry. Elm also makes a good wood for bed slats. An average price of $24.50 per thousand at the factory is reported. This is very little less than the average price reported for birch and maple for the same industry.

AGRICULTURAL IMPLEMENTS.

Over 7,000,000 feet of elm annually is reported as used for agricultural implements. It serves principally as the framework and as bent wood in many different kinds of farm implements, for which it is especially suitable, because it is comparatively light, strong, and serviceable. Cork elm and white elm are in demand for parts of cultivators, hayrakes, hay balers, thrashing machines, and reapers. White elm is commonly used for drill boxes. Cork elm is in good demand for plow handles because of its strength, ability to stand shock well, hardness, adaptability to bent work, and ability to take a smooth polish and wear smooth with use. The average cost of elm reported for these uses is $30.89 per thousand feet at the factory. Evidently a high quality of elm is demanded.

TRUNKS AND VALISES.

One of the most suitable uses for elm is for trunks. It often goes into the framework. Its chief place, however, is in the slats on the outside, where it is extremely resistent to wear and not easily broken. Few woods are considered equal to elm for this purpose. An average cost of $26.53 per thousand feet is reported by the factories.

FIXTURES.

Elm is in good demand by makers of church furniture, by whom it is made principally into curved pew seats. They like it because it bends well without steaming and glues well. The seats are built up from kiln-dry elm squares, which are glued together and held in the curved form until the glue is dry. The partly finished seat retains its curved shape when the pressure is removed. The seat is next shaped and finished by special machinery. The ends of the pews are usually made of oak, and the elm is stained to match it. Occasionally elm is used for the entire pew.

Cabinets and store and office fixtures are occasionally made of elm. The average price reported for elm for fixtures is $28.32 per thousand feet. This is considerably higher than the average price of this wood for furniture.

PLANING-MILL PRODUCTS, SASH, AND DOORS.

That there is a demand for elm for house and office finish is shown by the use of more than 6,000,000 feet annually for such purposes. It serves as an excellent inside finish wood because of its moderate amount of figure and pleasing light and dark shades when finished in the natural color, and makes a good appearance in panels. It is also used to imitate other woods which are more expensive, such as plain oak. A low average price ($19.05 per thousand feet) is reported for this class of products.

SPORTING AND ATHLETIC GOODS.

Cork elm is used for such products as horizontal bars and similar parts of gymnasium apparatus because of its ability to stand hard usage. White elm, finished in imitation of oak and birch, is used for low-priced billiard tables.

An average price of $30.24 per thousand board feet is reported for these uses.

HANDLES.

Elm is a suitable wood for handles because it is strong and serviceable. It is particularly in demand for certain kinds of handles, such as pike poles and cant-hook handles. Cork elm is well adapted for scythe snaths because of its strength and adaptability to bent work and because it takes a very smooth polish. Elm is not in favor for long handles, such as are used for hoes and hand rakes. It is light and strong, but its tendency to warp and twist when it absorbs moisture is a decided disadvantage. Ash is preferred for such uses.

The average price reported for elm used for handles is $17.35.

TOYS.

More than 2,000,000 feet of elm is reported as used for toys each year. Much of it goes into children's wagons and sleds.

The average cost reported for this purpose is $26.61 per thousand feet.

LAUNDRY APPLIANCES.

The good scrubbing and wearing qualities of elm when kept in contact with water make it popular material for parts of washing machines, washboards, and wash benches.

For these uses $26.96 per thousand feet is the average cost at the factory.

CAR CONSTRUCTION.

More than a million feet of elm annually has been reported as used for the interior parts of railway cars and locomotives. This is approximately one-tenth of all wood reported for this industry. Its use for this purpose is no doubt due to its strength and its shock-resisting properties, combined with its ability to take different finishes in imitation of oak and birch. The average price paid is $28.63 per thousand f. o. b. factory.

MISCELLANEOUS USES.

Elm is used in quantities of less than a million board feet annually in a large number of industries.

It was formerly a very important wood in shipbuilding on account of its shock-resisting qualities, strength, and cleaning properties. It is still in demand by barge builders and makers of small boats, but comparatively small amounts are now used by shipbuilders. The principal uses reported are for the bottom boards of canoes and the ribs of rowboats and motor boats.

Elm serves well for wooden parts of electrical machinery and apparatus. It is used in playground equipment, such as croquet sets, hammocks, and lawn swings. It is a satisfactory wood for saddletrees, harness, neck yokes, and stirrups.

Other kinds of products into which comparatively small amounts of elm are made are pulleys and conveyors, signs and supplies, brushes, dowels (principally for furniture), gates, and fencing.

ROUGH BUILDING CONSTRUCTION.

Elm is often used for bridge planking and for bridge and trestle timbers. Rock elm is preferred for bridge planking and is usually used 2 inches thick. Such planking sells for about $20 a thousand board feet. Thicker material, of course, costs more. Elm is sometimes made into lath, for which its strength makes it suitable. The total amount of elm used for these purposes is comparatively small.

CROSSTIES.

On account of its strength, hardness, and ability to withstand shock well, elm is a desirable wood for railway crossties. Since it does not resist decay in moist situations as well as many other woods, it should be treated with preservatives for use in ties. In 1914, 43,330 elm ties were reported treated with preservatives, which was one-tenth of 1 per cent of all ties reported treated for that year. Nearly 2,000 were treated with creosote and the rest (over 41,000) with zinc chloride. In 1915, 50,846 elm ties were reported treated, which was about one-seventh of 1 per cent of all treated ties reported for that year. All were treated with zinc chloride.

FIREWOOD.

Elm is not generally considered a desirable wood for fuel, because it is difficult to work up into cordwood and to season. Its slowness in burning is another objection to its use, especially for domestic purposes, where quick heating is desired. Slippery elm, however, is fairly satisfactory on account of its comparative ease in splitting. Elm ranks high in respect to the heating value of the dry wood, a standard cord (8 feet long, 4 feet high, and 4 feet wide) being equal in heat value to a ton of coal, which puts it in the same class with oak, hickory, and beech. When there is a supply of elm timber and a scarcity of other fuels, considerable quantities of elm are utilized for fuel. The market value of fuel wood depends on its heating qualities, the rate at which it burns, its abundance and availability, and the demand for such material. In Michigan a "stove-wood" cord of elm (8 feet long, 4 feet high, and 16 inches wide) was reported as usually selling for from $2 to $2.25.

FARM USES.

Elm serves many good purposes on the farm. It is often used for flooring in stalls because it presents a rough surface and is easy on the hoofs of animals. Compared to other woods it resists abrasion well in wet situations. Rock elm makes excellent mauls and also may serve for the handles. It is put to a large number of local uses, especially where there is a good supply and other timbers are not available.

Elm is often used for fence posts, although it is not very durable in the untreated condition. Since the sapwood takes treatment well, it is advisable to apply some preservative to the wood when it is to be used for such purposes.[1]

Cedar elm is commonly used untreated for fence posts in Texas; and, although much inferior in lasting qualities to osage orange, mesquite, and the cedars of the region, the elm posts last many years in a dry climate.

GRADES USED BY DIFFERENT INDUSTRIES.

The proportion of the various grades of elm used in each of five different industries is given in Table 8. The No. 1 common grade is demanded in largest quantity by these industries. The vehicle, chair, and furniture industries can evidently use this grade to best advantage. Furniture, vehicle, and musical instrument makers demand also considerable No. 2 common. Musical instrument and agricultural implement factories have need for a good deal of high-grade elm. The last-named industry also finds place for much very low-grade lumber, while the other four industries buy little or none of the No. 3 common for the manufacture of their products. This grade is used largely for crating.

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[1] See Farmers' Bulletin 744, "The Preservative Treatment of Farm Timbers."

TABLE 8.—*Grades of elm used by different industries.*

Industry.	Firsts and seconds.	Common.		
		No. 1.	No. 2.	No. 3.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Vehicles	24	46	28	2
Chairs	27	58	15	
Musical instruments	50	25	25	
Furniture	23	43	34	
Agricultural implements	30	25	16	29
Average for 5 industries	31	39	24	6

GRADING RULES FOR ELM.

There are two sets of lumber-association rules under which elm is graded: The Hardwood Manufacturers' Association rules, which are used largely by manufacturers in the eastern and southeastern parts of the hardwood region of the Eastern United States, and the National Hardwood Lumber Association rules, which are used by manufacturers throughout the central and western parts of the hardwood belt and by the Michigan Hardwood Manufacturers' Association and the Northern Hemlock and Hardwood Manufacturers' Association.

Under the Hardwood Manufacturers' Association rules the grade is determined by an inspection of both sides of the board, and there are five grades for elm: Firsts and seconds, No. 1 common, No. 2 common, No. 3 common, and No. 4 common. Bright sap is admitted in all grades. In firsts and seconds (*FAS*) the pieces must be 6 inches and over wide and 8 feet and over long. A small number of specified defects are allowed, depending on the width. In No. 1 common the pieces must be 4 inches and over wide, 6 feet and over long. In general they must work 66⅔ per cent clear face. No. 2 common pieces are 3 inches and over wide, 4 feet and over long, and must work at least 50 per cent into sound cuttings. No. 3 common pieces are 3 inches and over wide and 4 feet and over long and must contain 25 per cent sound cuttings. Black sap is not a defect in No. 2 and No. 3 common. No. 4 common is a lower grade, including all unsound lumber capable of holding nails. It is used for cheap boxing, sheathing, crating, etc. These rules apply to all species of elm.

In the National Hardwood Lumber Association rules inspection is made from the poor side of the piece, and there are separate grading rules for soft (white) elm and rock (cork) elm. There are four grades: Firsts and seconds, No. 1 common, No. 2 common, and No. 3 common.

Firsts and seconds is a combined grade made up of widths 6 inches and over and lengths 8 to 16 feet. A small number of defects are admitted, according to surface measure, as specified. Nos. 1, 2, and 3 common are 3 inches and over wide and 4 feet and over long. No. 1 must work 66⅔ per cent clear face; No. 2, 50 per cent sound; and No. 3, 25 per cent sound. Black spots and black streaks are defects.

A general similarity is seen in these two sets of rules. Of course inspection on the poor side of the piece raises the quality of the lumber in a particular grade.

The National Hardwood Lumber Association grades cork elm lumber, called "rock elm," under the same rules as hickory and pecan, since they are largely manufactured into the same products. Four grades are specified: Firsts and seconds, No. 1 common, No. 2 common, and No. 3 common. Firsts and seconds are 4 inches and over wide, and a specified number of defects is allowed according to width and length of piece. No. 1 common is 4 inches and over wide, 4 feet and over long, and must work 66⅔ per cent clear face. No. 2 common is 3 inches and over wide, 4 feet and over long, and must work 50 per cent sound. No. 3 common is also 3 inches and over wide, 4 feet and over long, and must contain at least 25 per cent of sound cuttings.

LUMBER AND STUMPAGE VALUES.

LUMBER PRICES.

Table 9 gives the average value of elm lumber f. o. b. mills for different States and years as given in manufacturers' reports on annual lumber production. Tables 10 and 11 give the average wholesale price f. o. b. mill from 1909 to 1916, inclusive, for different grades of soft and rock elm lumber in various States. The tables are based on reports to the Forest Service of actual sales by a number of the largest manufacturers in the different States. Prices are quoted for lumber 1 inch (4/4) thick of the different grades, and for mill run, which consists of all grades combined.

The 1917 wholesale prices of different grades of soft and rock elm lumber in the principal centers of its distribution are given in Table 12. Table 13, which is based on actual sales, gives average wholesale prices of different grades of soft and rock elm lumber f. o. b. mills in Wisconsin. These prices apply to lumber practically all of which is manufactured and graded according to the National Hardwood Lumber Association's grading rules.

TABLE 9.—*Average value of elm lumber per 1,000 board feet (f. o. b. mills) in different States for different years.*

State.	1899	1904	1906	1907	1908	1909	1910	1911	1912	1915
United States	$11.47	$14.45	$18.08	$18.45	$18.40	$17.52	$18.67	$17.13	[1]$16.87	$16.98
Wisconsin	11.82	14.62	17.10	19.26	18.80	17.48	19.46	17.81	16.52	12.59
Michigan	10.94	13.83	18.51	20.28	20.82	19.96	21.88	18.75	17.50	18.15
Arkansas	10.91	8.49	14.57	13.38	14.41	14.92	14.61	14.15	......	15.32
Indiana	11.02	16.45	19.10	18.63	19.10	19.42	18.64	17.22	17.23	18.03
Ohio	12.28	16.47	18.64	19.59	18.85	20.21	19.77	18.24	......	18.31
New York	13.19	15.80	25.00	24.00	24.00	16.19	21.81	18.76	......	18.16
Missouri	10.32	13.41	15.32	14.02	14.34	15.18	16.50	15.92	......	14.83
Tennessee	8.80	13.56	15.59	13.83	14.44	13.53	15.11	12.84	......	16.38
Louisiana	10.00	......	......	15.39	13.76	13.91	13.94	14.58	......	15.15
Mississippi	......	12.95	......	14.51	14.78	15.05	15.79	15.00	......	14.92
Minnesota	9.04	12.26	......	15.51	14.68	14.47	13.80	14.40	......	13.93
Illinois	11.41	14.26	17.10	15.52	15.24	16.18	15.53	15.92	......	13.12
Kentucky	12.77	12.86	14.28	14.19	......	16.00	12.20	12.19	......	14.46
Iowa	12.57	14.61	......	16.99	16.24	19.28	17.94	17.09	......	19.71
Pennsylvania	12.32	19.77	17.98	15.98	16.54	16.19	16.10	17.67	......	15.95
Vermont	11.33	11.04	......	15.51	14.97	14.80	13.43	14.27	......	14.81
Maine	10.04	......	......	15.56	14.27	15.27	14.25	12.50	......	13.93
Texas	11.97	......	......	10.83	12.26	17.15	17.88	......	......	13.77
Oklahoma	12.30	......	......	15.74	10.65	13.06	12.57	12.50	......	13.61
North Carolina	......	......	......	16.50	14.00	23.33	17.33	......	......	14.79
West Virginia	......	14.31	......	26.89	12.96	14.06	......	......	......	......
Georgia	......	9.00	......	13.46	18.16	10.10	13.29	11.80	......	13.96
Alabama	17.19	......	......	15.12	16.58	17.88	12.68	10.93	......	15.11
New Jersey	11.36	28.00	......	26.32	20.62	24.25	21.00	......	......	14.86
South Carolina	......	......	......	19.38	15.00	19.58	17.00	......	......	14.75
Virginia	10.00	......	......	11.87	13.66	13.02	......	......	......	......
Connecticut	25.00	......	......	17.08	12.43	15.16	15.27	14.33	......	18.45
Massachusetts	......	......	......	14.69	11.54	13.44	14.38	13.67	......	13.58
New Hampshire	......	......	......	14.42	14.23	13.93	14.21	13.29	......	15.29
Maryland	......	......	......	15.54	9.40	13.30	13.25	12.60	......	13.33
Rhode Island	......	......	......	12.12	18.00	14.00	......	......	......	......
Florida	......	......	......	......	......	12.00	......	......	......	......
Delaware	......	......	......	......	......	14.33	......	......	......	......
Kansas	12.75	12.86	......	......	......	16.00	18.67	......	......	......
Nebraska	10.41	......	......	......	......	......	......	......	......	......

[1] 1912 values based on a limited number of reports.

TABLE 10.—*Average wholesale price of soft elm lumber (per 1,000 board feet) in various States, based on actual sales made f. o. b. mill, for the years 1909–1916.*

SOFT ELM.

State and grades.	1909	1910	1911	1912	1913	1914	1915	1916
Arkansas:								
No. 1 common and better 4/4	......	$18.48	$21.08	$22.83	......	......	......	......
No. 2 common and better 4/4		14.88	15.62	17.15	......	......	......	......
Mill run	$14.65	14.60	15.46	16.25	......	......	......	......
Connecticut:								
Mill run	15.00	......	......	......	......	......	......	......
Illinois:								
No. 1 common and better 4/4	18.05	......	......	......	......	......	......	......
Mill run	15.45	15.00	15.92	......	......	......	......	......
Indiana:								
Firsts and seconds 4/4	22.60	......	......	......	......	......	......	......
No. 3 common 4/4	15.12	......	......	......	......	......	......	......
No. 1 common and better 4/4	20.78	22.40	23.48	23.03	......	......	......	......
No. 2 common and better 4/4	......	16.76	18.88	20.66	......	......	......	......
Mill run	18.59	18.64	19.00	17.23	......	......	......	......
Iowa:								
Mill run	......	......	17.08	......	......	......	......	......
Kentucky:								
No. 2 common and better 4/4	......	15.50	......	......	......	......	......	......
Mill run	......	......	......	14.50	......	......	......	......
Louisiana:								
Mill run	......	16.00	15.50	......	......	......	......	......
Massachusetts:								
Mill run	17.33	......	......	......	......	......	......	......
Michigan:								
Firsts and seconds 4/4	33.50	......	......	......	$40.00	$39.88	$38.69	$39.50
No. 1 common 4/4	......	......	......	......	29.33	29.88	28.69	29.50
No. 2 common 4/4	......	......	......	......	22.00	22.38	19.88	19.00
No. 3 common 4/4	11.35	......	......	......	14.88	15.66	13.99	14.18
No. 1 common and better 4/4	26.40	27.30	29.16	28.27	......	......	......	......
No. 2 common and better 4/4	......	24.17	24.01	25.63	28.81	27.50	26.02	29.59
No. 3 common 6/4	......	......	......	......	......	......	16.00	16.00

TABLE 10.—*Average wholesale price of soft elm lumber (per 1,000 board feet) in various States, based on actual sales made f. o. b. mill, for the years 1909–1916*—Continued.

SOFT ELM—Continued.

State and grade.	1909	1910	1911	1912	1913	1914	1915	1916
Michigan—Continued.								
Firsts and seconds 8/4	......	......	......	......	......	......	$36.25	......
No. 1 common 8/4	......	......	......	......	......	......	26.25	......
No. 2 common 8/4	......	......	......	......	......	......	16.25	......
Mill run	$21.19	$20.59	$19.00	......	$23.65	$21.87	22.08	$24.98
Mississippi:								
No. 2 common and better 4/4	......	15.75	14.92	......	......	......	......	......
Mill run	15.62	15.79	15.00	$15.84	......	......	......	......
Missouri:								
Firsts and seconds 4/4	29.25	......	......	......	......	......	......	......
No. 3 common 4/4	15.75	......	......	......	......	......	......	......
No. 1 common and better 4/4	......	15.00	......	......	......	......	......	......
Mill run	14.55	16.50	14.88	12.33	......	......	......	......
New York:								
No. 3 common 4/4	14.00	......	......	......	......	......	......	......
No. 1 common and better 4/4	......	......	......	25.00	......	......	......	......
No. 2 common and better 4/4	......	26.00	18.00	......	......	......	......	......
Mill run	20.63	20.44	20.50	18.84	......	......	......	......
Ohio:								
Firsts and seconds 4/4	27.50	......	......	......	......	......	......	......
No. 3 common 4/4	14.62	......	......	......	......	......	......	......
No. 1 common and better 4/4	22.67	24.23	22.47	24.75	......	......	......	......
No. 2 common and better 4/4	......	17.22	17.06	19.17	......	......	......	......
Mill run	18.74	18.38	18.18	15.71	......	......	......	......
Pennsylvania:								
Mill run	......	......	17.67	16.67	......	......	......	......
Tennessee:								
Mill run	16.67	15.11	......	......	......	......	......	......
Vermont:								
Mill run	......	17.25	17.50	15.40	......	......	......	......
Wisconsin:								
Firsts and seconds 4/4	29.00	......	......	......	......	......	33.50	36.50
No. 1 common 4/4	......	......	......	......	......	27.00	22.75	24.50
No. 2 common 4/4	......	......	......	......	......	......	14.50	14.75
No. 3 common 4/4	9.45	......	......	......	15.22	14.33	11.37	12.14
No. 1 common and better 4/4	22.19	24.68	25.14	26.02	......	......	......	......
No. 2 common and better 4/4	......	20.67	19.53	19.78	24.73	25.22	23.67	26.50
Mill run	17.32	16.80	16.74	15.20	21.03	14.00	17.46	18.62

TABLE 11.—*Average wholesale price of rock elm lumber (per 1,000 board feet) in various States, based on actual sales made f. o. b. mill, for the years 1909–1916.*

ROCK ELM.

State and grades.	1909	1910	1911	1912	1913	1914	1915	1916
Arkansas:								
Mill run	......	......	......	$16.33	......	......	......	......
Indiana:								
Firsts and seconds 8/4	$27.50	......	$37.57	36.34	......	......	......	......
No. 1 common 8/4	26.66	......	......	......	......	......	......	......
No. 1 common and better 8/4	......	......	29.00	27.50	......	......	......	......
No. 2 common and better 8/4	......	......	......	22.75	......	......	......	......
Mill run	19.38	......	19.83	......	......	......	......	......
Michigan:								
Firsts and seconds 8/4	......	......	......	......	......	......	......	......
No. 2 common 8/4	......	......	......	......	......	......	......	......
No. 3 common 8/4	11.72	......	......	......	$12.00	$12.00	......	......
No. 1 common and better 8/4	......	......	23.33	......	......	......	......	......
No. 2 common and better 8/4	......	$28.98	24.29	26.08	26.50	27.50	$28.00	......
Mill run	25.65	23.16	24.00	21.50	19.49	......	......	......
New York:								
Mill run	......	23.17	22.50	......	......	......	......	......
Ohio:								
Firsts and seconds 8/4	18.00	......	......	......	......	......	......	......
Mill run	16.50	21.05	18.38	16.33	......	......	......	......
Vermont:								
Mill run	......	15.67	15.83	......	......	......	......	......
Wisconsin:								
Firsts and seconds 8/4	38.12	33.60	32.68	33.18	......	40.00	......	$46.00
No. 1 common 8/4	27.38	......	......	......	......	......	......	36.00
No. 2 common 8/4	......	......	......	......	17.50	22.00	......	22.00
No. 3 common 8/4	10.07	......	......	......	13.62	16.00	......	11.33
No. 1 common and better 8/4	......	24.31	26.31	23.72	......	......	......	......
No. 2 common and better 8/4	......	24.81	22.41	21.97	25.08	26.31	23.54	30.02
Mill run	22.69	21.40	18.88	17.84	22.87	......	17.00	19.00

TABLE 12.—*Wholesale prices*[1] *(per 1,000 board feet) of elm lumber in important centers of lumber distribution and utilization.*

SOFT ELM.

	First and seconds, 6 inches and up wide.			No. 1 common, 4 inches and up wide.			No. 2 common, 3 inches and up wide.			No. 3 common, 3 inches and up wide.			Log run, M. C. O.		
	1 inch.	1½ inches.	2 inches.	1 inch.	1½ inches.	2 inches.	1 inch.	1½ inches.	2 inches.	1 inch.	1½ inches.	2 inches.	1 inch.	1½ inches.	2 inches.
Boston	$49.00	$51.00	$53.00	$39.00	$41.00	$43.00	$29.00	$31.00	$33.00	$24.00	$25.00	$26.00	$39.00	$41.00	$43.00
New York	48.00	50.00	52.00	38.00	40.00	42.00	28.00	30.00	32.00	23.00	24.00	25.00	38.00	40.00	42.00
Rochester	47.50	49.50	51.50	37.50	39.50	41.50	27.50	29.50	31.50	24.00	25.00	26.50	36.00	39.00	41.50
Buffalo	46.00	48.00	50.00	36.00	38.00	40.00	26.00	28.00	30.00	21.00	22.00	23.00	36.00	38.00	40.00
Philadelphia, Baltimore, and Washington	47.00	49.00	51.00	37.00	39.00	41.00	27.00	29.00	31.00	22.00	23.00	24.00	37.00	39.00	41.00
Pittsburgh	46.00	48.00	50.00	36.00	38.00	40.00	26.00	28.00	30.00	21.00	22.00	23.00	36.00	38.00	40.00
Richmond and Norfolk													28.00	31.00	32.00
Cincinnati and Kenova													26.50	29.50	31.50
Evansville													26.50	29.50	31.50
Indianapolis	45.00	47.00	49.00	35.00	37.00	39.00	25.00	27.00	29.00	20.00	21.00	22.00	35.00	37.00	39.00
Chicago	42.00	44.00	46.00	32.00	34.00	36.00	22.00	24.00	24.00	17.00	18.00	18.00	32.00	34.00	36.00
Cleveland	45.50	47.50	49.50	35.50	37.50	39.50	25.50	27.50	29.50	20.50	21.50	22.50	35.50	37.50	39.50
Detroit and Grand Rapids	42.00	44.00	46.00	32.00	34.00	36.00	22.00	24.00	26.00	17.00	18.00	19.00	32.00	34.00	36.00
Wausau, Wis.	39.00	41.00	43.00	29.00	31.00	33.00	19.00	21.00	23.00	14.00	15.00	16.00	29.00	31.00	33.00
St. Paul and Minneapolis	40.50	42.50	44.50	30.50	32.50	34.50	20.50	22.50	24.50	15.50	16.50	17.50	30.50	32.50	34.50
St. Louis													25.50	28.50	30.50
Kansas City													28.00	31.00	33.00
Denver													36.50	38.50	40.50
Los Angeles, San Francisco, and Seattle	61.00	63.00	65.00												
Cairo and Thebes													24.50	27.50	29.50
Memphis	28.00	31.00	34.00	18.00	21.00	24.00	13.00	15.00	17.00	9.00	11.00	13.00	19.00	24.00	24.00
New Orleans													22.00	26.00	28.00

ROCK ELM.

	4 inches and up wide.			3 inches and up wide.											
Boston	$53.00	$55.00	$57.00	$43.00	$45.00	$47.00	$29.00	$31.00	$33.00	$26.00	$27.00	$28.00	$38.00	$41.00	$43.00
New York	52.00	54.00	56.00	42.00	44.00	46.00	28.00	30.00	32.00	25.00	26.00	27.00	37.00	40.00	42.00
Rochester	51.00	53.00	55.00	41.00	43.00	45.00	27.00	29.00	31.00	24.00	25.00	26.00	36.00	39.00	41.00
Buffalo	49.00	51.00	53.00	39.00	41.00	43.00	25.00	27.00	29.00	22.00	23.00	24.00	34.00	37.00	39.00
Philadelphia, Baltimore, and Washington	51.00	53.00	55.00	41.00	43.00	45.00	27.00	29.00	31.00	24.00	25.00	26.00	36.00	39.00	41.00
Pittsburgh	49.00	51.00	53.00	39.00	41.00	43.00	25.00	27.00	29.00	22.00	23.00	24.00	34.00	37.00	39.00
Indianapolis	48.00	50.00	52.00	38.00	40.00	42.00	24.00	26.00	28.00	21.00	22.00	23.00	33.00	36.00	38.00
Chicago	44.50	46.50	48.50	34.50	36.50	38.50	20.50	22.50	24.50	17.50	18.50	19.50	29.50	32.50	34.50
Cleveland	47.50	50.50	52.50	38.50	40.50	42.50	24.50	26.50	28.50	21.50	22.50	23.50	38.50	36.50	38.50
Detroit and Grand Rapids	44.50	46.50	48.50	34.50	36.50	38.50	20.50	22.50	24.50	17.50	18.50	19.50	29.50	32.50	34.50
Wausau, Wis.	41.00	43.00	45.00	31.00	33.00	35.00	17.00	19.00	21.00	14.00	15.00	16.00	26.00	29.00	31.00
St. Paul and Minneapolis	43.00	45.00	47.00	33.00	35.00	37.00	19.00	21.00	23.00	16.00	17.00	18.00	28.00	31.00	33.00
Kansas City	46.00	48.00	50.00	36.00	38.00	40.00	26.00	28.00	30.00	21.00	22.00	23.00	36.00	38.00	40.00
Denver	50.00	52.00	54.00	40.00	42.00	44.00	30.00	32.00	34.00	25.00	26.00	27.00	40.00	42.00	44.00
Los Angeles, San Francisco, and Seattle	68.00	70.00	72.00	....	....	....	....	....	....	....	....	....	....	....	....

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[1] From the market report of Feb. 15, 1917, of the Lumbermen's Bureau, Washington, D. C. These prices are reported to represent actual selling prices in the principal markets of lumber in car lots to the retail and factory trade.

TABLE 13.—*Average wholesale prices*[1] *of elm lumber (per 1,000 board feet) f. o. b. mill, based on actual sales by mills in Wisconsin, January and February, 1917.*

Grade.	Soft elm.		Rock elm, 8/4.
	4/4	6/4	
Firsts and seconds	$36.63	$43.08	$48.36
No. 1 common	26.87	32.94	37.36
No. 2 common	18.14	21.75	19.00
No. 3 common	14.42	15.33	16.37
No. 2 common and better	24.91	30.57	....

[1] Figures compiled from prices of actual sales published in the weekly bulletin of the Northern Hemlock and Hardwood Manufacturers' Association.

TABLE 14.—*Average stumpage values of elm for 1907 and 1912.*

State and group.	1907	1912
Northeastern States:		
Maine	$3.00 (7)	$3.71 (26)
New Hampshire	4.65 (10)	5.25 (8)
Vermont	4.07 (15)	4.25 (12)
New York	5.07 (14)	6.17 (56)
Pennsylvania	5.35 (30)	5.93 (31)
Average of 5 States	4.74 (76)	5.40 (133)
North Central States:		
Ohio	7.11 (37)	9.43 (76)
Indiana	7.64 (52)	7.78 (78)
Average of 2 States	7.42 (89)	8.59 (154)
Southern Appalachian States:		
Maryland	4.50 (2)	4.56 (8)
Virginia	2.17 (6)	2.67 (3)
West Virginia	2.19 (8)	3.00 (1)
Kentucky	3.82 (24)	4.09 (29)
Tennessee	2.29 (13)	2.80 (33)
North Carolina	....	3.70 (5)
Average of 6 States	3.04 (53)	3.51 (79)
Lake States:		
Michigan—		
Upper Peninsula	4.03 (19)	....
Lower Peninsula	8.34 (62)	....
Southern tier of counties	9.67 (6)	....
State average	7.49 (87)	8.77 (82)
Wisconsin	4.72 (76)	5.01 (112)
Minnesota	4.22 (9)	6.70 (33)
Average of 3 States	6.10 (172)	6.61 (227)

NOTE.—The numerals in parentheses indicate the number of reports on which the averages are based. Taken from Department of Agriculture Bulletin 285, The Northern Hardwood Forest, Table 12.

VALUE OF STANDING TIMBER.

Census reports on manufactures for 1899 give a stumpage price for elm of $3.43 per thousand board feet for Michigan and $2.39 for Missouri, and an average for the United States of $3.30. In the report for the year 1904 the price had risen to $5.58 per thousand for the United States. Census figures for later years are not available. Table 14 gives average stumpage values of elm by States and groups of States for 1907 and 1912. These figures are averages of estimates by timberland owners. Reports of actual sales of stumpage in 1912 collected by the Forest Service give an average price of $8.40 per thousand board feet in the Northeastern States (Maine, New Hampshire, Vermont, Massachusetts, New York, and Pennsylvania), $5.87 in the Lake States (Michigan, Wisconsin, and Minnesota), and $3.41 in the Southern States (Maryland, Virginia, West Virginia, Kentucky, Tennessee, and North Carolina). Although based on many reports of actual sales, these figures show only general tendencies of stumpage prices in these three regions.

Elm stumpage is now largely bought up by slack cooperage and basket manufacturers, etc. Factories which can not use other woods in place of elm can usually afford to pay better prices for it than can the lumber manufacturers. An average price paid for soft elm on the stump by factories in southern Michigan would be about $12 per thousand board feet. The logs usually bring from $15 to $20 at the factory. In the lower Mississippi Valley the prices are somewhat lower. Firms cutting their own timber in that section figure that elm logs are worth about $8 per thousand board feet at the mill. This is about what it costs to cut and transport to the mill, allowing for stumpage only $1.50 per thousand feet, for which mixed hardwood timber has been purchased in that region. A good quality of elm stumpage, of course, brings a much higher figure, depending on quality, amount, accessibility, etc. Rock-elm stumpage ordinarily sells for from $15 to $20, and at the factory the logs sell for about $25 on the average. A high grade of rock elm sells for higher prices for special purposes. It is reported that as much as $65 per thousand has been paid in southern Michigan for rock-elm stumpage, only choice trees here and there being selected.[1]

COST OF LUMBER PRODUCTION.

Since elm is commonly manufactured into lumber along with other woods with which it grows in mixture, the cost of converting it into lumber is difficult to ascertain. A theoretical cost can of course be obtained by subtracting the stumpage value from the mill-run value of the timber at the mill. For instance, subtracting the 1912 value of elm stumpage in Michigan (Table 14), which is about $9, from the average mill-run value of soft elm lumber, which is approximately $25, leaves $16, which represents the cost of production per thousand board feet, including the lumber manufacturers' profit.

Portable sawmills in Michigan generally charge from $4 to $4.50 per thousand board feet for sawing. The lumber produced by these mills, however, is often not well manufactured, and not so valuable for many purposes as that turned out by large stationary mills. There is also usually more waste in the portable mill.

MARKETS.

Elm timber may be disposed of on the stump, in the log, or in the form of manufactured lumber. Considerable quantities are supplied from woodlots by farmers who sell the logs to wood-using factories or to local sawmills.

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[1] These prices were compiled, in part, from quotations furnished by the Michigan Agricultural College, Lansing, Mich.

Slack-cooperage factories afford a good market for elm in the log. They demand sound, straight-grained timber with clear boles and few knots. Hoop makers in the lower Mississippi Valley generally pay from $12 to $18 per thousand board feet for delivered logs, depending on the quality. A good grade of elm logs delivered at the railroad in Arkansas should bring $15 a thousand board feet log scale. Manufacturers are often able, however, to secure their elm at a lower figure. Factories along the Mississippi River can usually secure mixed hardwood logs in rafts, including elm, gum, cottonwood, sycamore, and ash, for from $8 to $10 a thousand board feet. A good grade of elm logs when sold alone will usually bring from $13 to $14 per thousand feet. Slack-cooperage firms are often able to buy mixed timber, including elm, on the stump at a low figure and transport the logs to the factory at a total cost of $8 a thousand, including the stumpage price. In Michigan and Wisconsin about $20 per thousand is the usual price for good-quality logs delivered. Hoop factories can use the logs as small as 12 inches in diameter at the small end, and the usual lengths are 12, 14, and 18 feet.

Factories making baskets and fruit and vegetable packages consume large quantities of elm in the log and generally pay on the average about $18 a thousand in southern Michigan and Wisconsin. Cheese-box factories get practically all their wood in the log, and the elm is purchased at an average price between $15 and $16 per thousand. Such factories can utilize low-grade material. These prices are for soft elm logs f. o. b. factory. Where there is a demand for rock elm in the log, a better price should be secured than for the soft elm. A good quality of practically clear rock elm in the log may bring a high price where it is necessary for the manufacture of certain products, as for parts of vehicles.

There was formerly a good demand for high-grade cork elm in the log or bolt by wheel makers for hubs, but this demand is now comparatively small. Pieces in the round as small as 4 inches are utilized, and material must be practically clear.

Elm logs are often sold according to grade. The Hardwood Manufacturers' Association of the United States specifies three grades of elm logs: No. 1, select, and No. 2. No. 1 logs are 24 inches and over in diameter, select are 18 inches and over, and No. 2 are 16 inches and over. The grade is otherwise determined, in each diameter, by the number of defects. Bright sap is not considered a defect. Purchasers often have log specifications of their own, which are altogether different from those just given, and are suited to their own requirements.

Where there is a considerable amount of elm and other good-saw timber, it may be more profitable to convert it into lumber than to dispose of it in the log. It should be remembered, however, that well-manufactured lumber is much more valuable than lumber that is poorly manufactured. Some of the product turned out by portable sawmills can not command good prices for this reason. It usually pays well to exercise care in securing exact and uniform sizes of lumber. Graded lumber can usually be sold at a higher price than the ungraded or "mill run" because its quality is better known. The manufacturer can also generally use the graded stock to better advantage, because it is better suited to his special requirements.

Manufacturers of vehicle stock buy considerable cork and white elm, and a good price can usually be obtained for high-grade material. There is a good demand by automobile body makers for thick material of cork elm and for white elm suitable for bending. Chair factories also use considerable elm in bent work and can generally utilize large amounts of No. 1 common and better grades. Manufacturers of other elm products, such as furniture, chairs, church pews, and agricultural implements, also usually buy graded lumber to meet their requirements. Factories often buy a certain combination of grades. Furniture factores, for instance, often buy a "No. 1 common and better" grade. Some factories find it an advantage to buy as low as "No. 3 common and better" and use the lowest grade for crating.

Timber owners often can secure valuable information on markets from State foresters, forest and agricultural schools, and the United States Department of Agriculture.[1] Lists of uses for elm are given on pages 39 to 43 of this bulletin.

ELM IN THE WOODLOT.[2]

With the great modern reduction in the timber supplies of the country, the farm woodlot has constantly gained in importance as a source of timber for both local and general consumption. Elm, while rarely very abundant in woodlots, is still of frequent occurrence in them.[3] The different kinds are rather alike in their growth needs.

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[1] Woodlot owners should secure Farmers Bulletin 715, "Measuring and Marketing Woodlot Products."

[2] Prepared by E. H. Frothingham, Office of Forest Investigations.

[3] An idea of the degree of prevalence of elm in woodlots is given in the following statement, compiled from reports of woodlot owners in different States and counties. The figures have no relation to the abundance of elm, but simply give the percentage of the woodlots examined which contained elm, whether in large or in small quantity:

Percentage of woodlots examined which contained elm.

Region.	Per cent.
Northeastern Connecticut (Windham County)	1.3
Northwestern Vermont (Franklin County)	8.2
Northern Indiana (Kosciusko County)	53.3
Central Indiana (Madison County)	68.4
Southern Indiana (Jackson County)	16.2
Central Wisconsin (Marathon County)	46.8
Southern Minnesota (McLeod County)	84.0
Eastern Iowa (Jones County)	53.3
Southeastern Nebraska (Gage County)	54.3
Central Tennessee (Rutherford County)	40.0

All need much light, and so do best when their crowns are well above those of their neighbors. This is the usual position of white elm, at least, in the old-growth forests. All make their best growth in good deep, fresh, or moist soil with good drainage, but will succeed even on upland sandy or stony soil, if not too dry and shallow. Where creeks run through woodlots, elms are more apt to be found along their borders among such trees as maple, beech, birch, white and red oaks, and basswood. Among the oaks, hickories, pine, etc., which commonly occupy the drier sites, elms are usually rare or absent. In woodlots in river bottoms white elm is often one of the most abundant trees, growing among cottonwoods, silver maples, sycamores, and other moisture-loving species.

Most of the woodlot elm is white elm, especially in the region north of central Ohio, Indiana, and Illinois. This is rather unfortunate, since for woodlot purposes white elm is probably the least useful of the three common species (white, cork or "rock," and slippery or "red" elm). Its growth rate, while only moderate, is more rapid than that of the other species, but the usefulness of the wood for farm purposes is less. It is less desirable than slippery elm for fuel, and probably somewhat less resistant to decay and therefore less useful for fence posts, sills, etc. For lumber or bolts intended for wagon manufacture and similar purposes, cork elm is, of course, superior to the other species.

Where mature elm of either of these three species, or young, thrifty trees of cork or slippery elm are present in a woodlot they should be counted a resource; but it is often of doubtful advisability to plant elm or attempt to secure natural reproduction, for the purpose of producing wood. Efficiency in woodlot management or planting demands careful discrimination as to species, and various species of oak, pine, etc., may often be better material, depending on soil, drainage, and economic conditions, than elms. Before making the choice as to trees to be planted or favored in woodlots, owners should secure whatever information is available with reference to the different useful species and the conditions under which each is worthy of selection. Advice on such questions can usually be obtained easily from State foresters in the States which employ them, from forest schools, or from the Forest Service, United States Department of Agriculture.[1]

SUMMARY AND CONCLUSIONS.

The value of elm wood for special purposes is due to its strength, excellent bending qualities, and high degree of ability to stand shock. These properties make it valuable for hoops of various kinds, basket rims and handles, bent work in vehicles and chairs, and framework of such products as furniture and agricultural implements.

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[1] The following bulletins of the United States Department of Agriculture contain information which may be of use to woodlot owners in this connection:

Bulletin 153, "Forest Planting in the Eastern United States."
Bulletin 481, "Status and Value of Farm Woodlots in the Eastern United States."
Farmers' Bulletin 711, "Care and Improvement of the Woodlot."

Elm is becoming scarce, and consequently higher priced. In the region of the Great Lakes, where the largest supply has been, factories often find it difficult to get a sufficient quantity, and many of them have been forced to remove to the lower Mississippi Valley region for a new supply.

A fairly constant, though probably diminishing, supply of elm is assured for a long time to come because the different elm species, taken altogether, have a wide range and form an appreciable percentage of the mixed hardwood stand throughout the eastern half of the United States. In many strictly agricultural areas elm is often found near streams and on lands not suitable for tilling. Farmers' woodlots, which have furnished a large part of the past supply of elm, can not be depended upon, however, for a constant future supply, because farmers will prefer more rapid growth and more widely useful species.

The future use of elm will be restricted for the most part to those purposes for which other species are not satisfactory. On account of the higher price and increasing scarcity of the supply, manufacturers are substituting many other woods for elm where this is possible.

Elm in the log can be best utilized for hoops, parts of baskets, and such articles as cheese-box rims. A good grade of elm is required for bent work by manufacturers of different kinds of vehicles and furniture. The cork elm and dense second-growth material of other elm species is particularly in demand by vehicle makers, especially automobile-body manufacturers, and for certain kinds of woodenware articles. Large amounts of low-grade elm are used by factories for crating.

Timber owners are often enabled to find a suitable market by writing to the Forest Service, United States Department of Agriculture, and to State forestry officials.

CLASSIFIED USES OF ELM IN DIFFERENT WOOD-USING INDUSTRIES.

WHITE ELM.

Agricultural implements.—Cultivator frames, cultivators, drill boxes, fishbacks, harrows, hay balers, hay racks, hayrakes, plow handles, machine platforms, potato diggers, press racks, root cutters, seeder rims, shoveling-board cleats, spraying machines, stump pullers.

Baskets and crates.—Bails, basket; bands, basket; bottoms, basket; baskets, banana; baskets, bushel; baskets, fruit; baskets, grain; baskets, grape; baskets, shipping; baskets, splint; baskets, split; baskets, vegetable; baskets, waste; box shooks; boxes, apple; boxes, candy; boxes, cigar; boxes, comb; boxes, knife; boxes, seed; boxes, trunk; boxes, veneer; boxes, wheelbarrow; boxes, woven; cases, egg; cleats, bottom; crates, bushel; crates, egg; crates, onion; crates, potato; crating; crating, automobile; crating, buggy; crating, carriage; crating, wagon; frames, banana carriers; hampers, banana; hampers, clothes; handles, basket; hoops, basket; packages, fruit; packages, vegetable; packing, fruit.

Brushes.—Brush backs; brush blocks.

Car construction.—Car repairing; cars, electric; locomotive cabs, interior; railway coaches; tie plugs.

Dairymen's and poulterers' supplies.—Brooders; cheese-box frames; cheese-box rims; cheese boxes; coops, chicken; dashers; incubators; poultry roosts.

Dowels.—Dowels.

Elevators.—Elevators.

Equipment, playground.—Bent hammock spreaders; hammocks, porch; merry-go-round parts.

Frames and molding.—Moldings, picture.

Furniture and fixtures.—Bed rails; Bible stands; bookcases, inside cork; cabinets; cabinets, medicine; cabinets, seed; cabinets, toilet; carvings; chair backs; chair bottoms; chair frames, upholstered; chair rods; chair-seat frames; chair seats; chair stock; chairs, bent; chairs, kitchen; chiffoniers; china closets, inside work; church furniture; commodes; commodes, inside work; costumers; cots; couch frames; couches; cribs; cupboards; davenport frames; davenports; drain boards; drawer ends; drawer sides; drawer tops; dressers; fixtures; fixtures, bank; fixtures, bar; fixtures, barber shop; fixtures, office; fixtures, store; furniture frames; furniture frames, upholstered; furniture, office; ice boxes; ice chests; kitchen-cabinet backs; kitchen-cabinet partitions; kitchen-cabinet posts; kitchen-cabinet shelves; kitchen cupboards; kitchen safes; lounge frames; mission furniture; music cabinets; opera chair backs; opera-chair seats; parlor cabinets, inside work; pew backs; pew ends; pew seats; pigeon-hole cases, desk; pulpits; refrigerators; rocker frames; rocker runners; rockers; shelves; showcases; sideboards; sofa frames; spring-bed frames; stands; table frames; table legs; table slides; tables; tables, billiard; tables, communion; tables, extension; tables, kitchen; tables, library; tables, parlor; wall cases; wardrobes.

Handles.—Handles; handles, cant-hook; handles, crosscut saw; handles, peavy; pike poles.

Instruments, musical.—Banjo necks; binders, piano backs; organs; piano backs; piano benches; piano bridges; piano posts; piano stools.

Insulator pins and brackets.—Insulator pins.

Laundry appliances.—Ironing boards; wash benches; washboards; washing machine dashers; washing machine parts.

Machine construction.—Folding machines; hose menders; machinery construction; power pump skids; roll paper cutters.

Machinery and apparatus, electrical.—Apparatus parts, electric; telephone accessories; telephone apparatus.

Patterns and flasks.—Flasks; flasks, foundry.

Planing-mill products.—Beams; finish; flooring; floors, cellar; interior finish; molding; sheathing.

Printing material.—Cases; printers' cabinets.

Pulleys and conveyors.—Pulleys; packing strips.

Pumps.—Buckets, pump.

Saddles and harness.—Cantles, saddletrees; hames; horse pokes.

Sash and doors.—Grain doors.

Ship and boat building.—Boat ribs; boats; boats, motor; boats, row; canoe-boat bottom boards.

Signs and supplies.—Signboards; signs, advertising.

Slack cooperage.—Headings; head linings; hoops; staves.

Sporting and athletic goods.—Tennis frame throats; billiard tables.

Tanks and silos.—Silo rims.

Toys.—Furniture, toy; sleds, toy.

Trunks and vehicle parts.—Automobile bodies; automobile-body framework; automobile body seat frames; automobile bows; automobile doors; automobile dusters, automobile floor boards; automobile running boards; bentwork; carriages and automobiles; bob sleds; buggy bows; buggy cushion frames; buggy hubs; cart trees; cutter bodies; cutter frames; doubletrees; eveners; eveners, wagon; go-cart rods; handles, cart; hubs, vehicle; hubs, wagon; hubs, wheelbarrow; rims, bicycle; singletrees; sled beams; sled runners; sleds, hand; sleds, mountain oscillator; sleigh runners; sleighs; spokes, wagon; stone boats; vehicle bodies; vehicle frames; wagon-bottom stock, wagon bows; wagon cleats; wagon repairing; wagon tongues; wheelbarrows.

Woodenware.—Bails, bucket and pail; barbers' checks; bushel measures; cheese boxes; coat hangers; game boards; hoops, bucket; hoops, woodenware; ironing boards; ladders; pails; pastry boards; pastry sets; plugs, paper roll; riddle rims; rungs, ladder; sieve rims; sieves, ash; sleeve boards; splints; traps, mouse; traps, rat; tubs.

SLIPPERY ELM.

Agricultural implements.—Compressers, hay balers'; doubletrees, plow and harrow; drill boxes; eveners; eveners, plow and harrow; harrow parts; hay baler parts; hay loader parts; hayrake parts; hoppers; machine handles; plow handles; seeder boxes, farm implements; vane slats, windmill; wheel slats, windmill.

Baskets and crates.—Baskets; box shooks; boxes; boxes, woven-wire; cases, egg; crates; crating; handles, basket; rims, basket.

Dairymen's and poulterer's supplies.—Butter-churn bows; butter-tub rims; stock racks.

Dowels.—Dowels.

Elevators.—Elevator platforms.

Equipment, playground.—Bent hammock spreaders; lawn swings.

Furniture and fixtures.—Buffets; church pews; fixtures; kitchen-cabinet shelving; kitchen cabinets; panels, veneered; refrigerators; rockers, chair.

Handles.—Handles.

Instruments, musical.—Banjo rims; piano backs; posts, piano backs.

Machine construction.—Engine skids; flour-mill machinery parts; gasoline-engine trucks; machine platforms, vender machines.

Pumps.—Sweeps.

Saddles and harness.—Neck yokes; ox yokes; saddletrees.

Slack cooperage.—Headings; hoops; staves.

Trunks and valises.—Trunks.

Vehicles and vehicle parts.—Bent panel backs, light vehicle; bentwork, carriage; hounds, vehicle; hubs; hubs, light vehicle; hubs, wagon; singletrees; sleigh runners; trucks, hand; wagon beds, coal; wagon reaches; whiffletrees.

Woodenware.—Game traps; ladders; ladders, store; lard tubs; mouse traps; rat traps; riddle rims; sieve frames; sieve rims; step chairs.

CORK ELM.

Agriculture implements.—Crossbars; doubletrees, plow and harrow; eveners; eveners, plow and harrow; feed cutters; grain boxes, corn planters; harrow parts; hay baler parts; hay-loader parts; hay racks; hayrakes; hoppers; hoppers, grain; machine handles; thrasher posts; wheat drill boxes.

Baskets and crates.—Baskets; baskets, vegetable; box shooks; boxes; boxes, cigar; boxes, packing; boxes, woven wire; cases, egg; crates; crating· hoops, basket; rims, basket.

Car construction.—Car construction; dump cars.

Dairymen's and poulterers' supplies.—Butter-tub rims; churns, butter.

Dowels.—Dowel rods; dowels.

Elevators.—Battens; beams, elevator cars; boxes, weight, dumb waiter; cleats, dumb waiter; elevator platforms; guide posts, dumb waiter; guide rails, dumb waiter; overhead beams, dumb waiter; shelves, dumb waiter.

Equipment playground.—Lawn swings.

Furniture and fixtures.—Buffets, inside work; chairs, wicker; kitchen cabinets; pews, church; posts, seat; rockers, chair; settees; settees, bent wood; tables, bent wood.

Handles.—Handles; handles, file; handles, machine; handles, snow shovel; scythe snaths.

Instruments, musical.—Piano cases.

Machine construction.—Engine skids; friction blocks, derrick; friction blocks, hoisting machine; gear parts, flour-mill machinery; grist mills; platforms; trucks, gasoline engine.

Machinery and apparatus, electrical.—Telephone pins.

Planing mill products.—Interior finish.

Printing material.—Printers' cabinets.

Pulleys and conveyors.—Cable rollers.

Saddles and harness.—Cantles; neck yokes; saddletrees; stirrups.

Ship and boat building.—Boats; launch-wheel drums; steering wheels.

Slack cooperage.—Headings; head linings; hoops; staves.

Sporting and athletic goods.—Horizontal bars.

Trunks and valises.—Sample cases; trunk slats; trunks.

Vehicles and vehicle parts.—Automobile bent seats; automobile body parts; automobile door pillars; automobile seats; baby carriages; bent frame backs; light vehicles; bent work; bob sleds; bows; buggy frames; cutter bodies; cutter frames; cutter runners; cutter stock; eveners; handcar frames; hand trucks; hounds, light vehicle; hounds, vehicle; hub blocks; hubs; hubs, carriage; hubs, light delivery wagon; hubs, light vehicle; push cars; railroad-velocipede handles; reaches; reaches, light vehicle; singletrees; sled knees; sled runners; sled runners, bent wood; sleds; sleigh bodies; sleigh runners; sleighs; spokes, wagon; truck rims; vehicle bodies; vehicle frames; wagon beds, wagon gears; wagon spokes; wagon tongues; wheel rims; wheel rims, automobile; wheelbarrows; whiffletrees.

Woodenware.—Bails, pail and bucket; chairs; step ladder; hoops, bucket; hoops, pail; hoops, woodenware; ladder rungs; ladders; lard tubs; mouse traps; sieve frames; sieve rims; sifter handles; stepladders; stools, stepladder; tent pins; tent slides; tubs, lard.

WING ELM.

Agricultural implements.—Agricultural implements (bent wood).

Baskets and crates.—Boxes; crates.

Furniture and fixtures.—Cabinet legs; bed slats.

Slack cooperage.—Staves; hoops.

Trunks and valises.—Suitcases; trunks.

Vehicles and vehicle parts.—Carriage shafts; wagon hubs; wagon poles.

Woodenware.—Hoops.

Saddles and harness.—Saddletrees.

ELM.

Agricultural implements.—Cradles; cradle bows; feed tables; grain drills; harvesters; hay racks; mower poles; reaper poles.

Baskets and crates.—Basket bottoms; basket covers; baskets; baskets, banana; baskets, fruit; baskets, grape; baskets, vegetable; boxes; boxes, cigar; bread-box slats; cases, egg; cases, fruit; crates, bushel; crates, fruit; crates, vegetable; crating; crating corners; crating posts; hoops, fruit package; hoops, vegetable package; package, fruit; package, vegetable; trays, grape.

Car construction.—Pullman-car repairing.

Caskets and coffins.—Coffins.

Dairymen's and poulterers' supplies.—Cheese-box heads; cheese-box hoops; coops.

Equipment, playground.—Croquet sets.

Furniture and fixtures.—Bed slats; bent work; cabinetwork; cabinets; camp furniture; chairs; chairs, children's; church furniture; couch frames; desks; drawer bottoms; fixtures; fixtures, store; framing, rattan furniture; furniture frames; refrigerators; rockers; seats, church pews; shelves, school desks; show-case bottoms; show-case panels; show-case tables; soda fountains; tables.

Gates and fencing.—Gates; fencing.

Handles.—Handles.

Instruments, musical.—Organs; panels, musical instruments; piano cases; piano parts; pianos; pipe organs; talking-machine horns.

Instruments, professional and scientific.—Tool chests.

Laundry appliances.—Laundry appliances.

Machine construction.—Horsepower; machine construction; paper-mill supplies.

Planing-mill products.—Finish; interior finish; planing-mill products.

Printing material.—Printers' supplies.

Pulleys and conveyors.—Conveyors; pulleys.

Sash and doors.—Sash.

Ship and boat building.—Barges; boat frames; boats; ship building; ships.

Sporting and athletic goods.—Sporting goods.

Toys.—Boys' sleds; boys' wagons; toys.

Trunks and valises.—Trunks.

Vehicles and vehicle parts.—Automobile bodies; axles; bows, bending; felloes; framing, baby carriage; hubs; sled; spokes; vehicle poles; wagons; wheel rims; wheelbarrows; whiffletrees.

Woodenware.—Grain measures; hoops; kegs; kits; oil-can jackets; pails; pails, tobacco; tubs; woodenware.

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THE SOURCES OF APPLE BITTER-ROT INFECTIONS.

By JOHN W. ROBERTS, *Pathologist, Fruit-Disease Investigations.*

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INTRODUCTION.

In the more southern apple-growing sections of the United States the disease having the common name bitter-rot or ripe-rot and caused by the fungus *Glomerella cingulata* is one of the most destructive with which growers have to contend. In some seasons it is undoubtedly the most destructive. The financial loss from apple bitter-rot is increased by the fact that whereas such diseases as scab, blotch, and blight destroy the crop in early spring or prevent its setting at all, bitter-rot does not ordinarily begin until July and usually does not complete its ravages until September or even later. The grower, then, may during the early part of the season spend his time and money spraying for the control of other diseases, such as scab and blotch, and of insect pests, only to see his fruit finally succumb to bitter-rot in midseason, often despite his best efforts to prevent it. As compared with the control of scab and blotch, which are also important apple diseases in the South, the control of bitter-rot is difficult of accomplishment. In the case of scab and blotch, definite times can be set for the application of sprays for control purposes, since these diseases appear only in the early part of the season when the apple is in a definite stage of development. With bitter-rot, however, infections may occur from about June 15 until well into September. If the weather is hot and moist and sources of infection are present in sufficient numbers, the whole crop may be destroyed within a week, almost before the orchardist is aware that the disease has broken out. The writer has seen cases in which the grower on visiting his orchard for the purpose of inspecting the crop preparatory to picking has been surprised to find every apple rendered worthless by bitter-rot, while only a few days before the crop had appeared to be entirely free from disease. Naturally such experiences as this cause southern growers to dread this rot more than any other disease affecting the apple, with the possible exception of pear blight.

Estimates of the annual losses caused by apple bitter-rot are very difficult to make with any degree of accuracy because of the great seasonal variation of the disease, due mainly to weather conditions and because of the variation in the amount of damage done in different sections from year to year. Local conditions also play a great part in the variations of this disease. A local shower on a hot July afternoon may supply just the right conditions of extreme heat and moisture to give the disease a beginning which finally may lead to the total destruction of the apple crop, whereas a few miles away conditions may be such that the disease is unable to gain headway all season.

Although the causal fungus is found in apple-growing sections of States farther north and also in Europe and Australia, bitter-rot is a serious disease only in the more southern apple-growing sections of this country. Apparently the fungus is to be found in practically every section of the world in which apples are grown, but is capable of causing very serious losses only under the warm moist weather conditions of the southern apple-growing sections of the United States. According to Edgerton (7)[1] and Schneider-Orelli (11), the fungus as it occurs in the northern United States and in Europe is physiologically different from the fungus associated with the serious bitter-rot of the Southern States.

Bitter-rot is typically a hot-weather disease. Accordingly, the hot weather of the South coupled with sufficient moisture for germination of the spores is peculiarly favorable to its development. Ideal weather for bitter-rot infections is furnished by high temperature and high humidity with the interspersion of frequent showers.

The earliest reference to apple bitter-rot is usually credited to Berkeley (2) in 1856, but Ricker (9) in 1916 discovered a reference to it in an unpublished manuscript by Coxe, dated May 30, 1829. In this manuscript, apple bitter-rot is referred to as being a common disease, and slaked lime placed about the tree is mentioned as having been advised as a remedial measure.

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[1] The serial numbers in parentheses refer to "Literature cited," at the end of this bulletin.

The fungus which causes bitter-rot of the fruit also causes a canker of apple branches. As the branch cankers are chiefly important as sources of rot infection, they will be described and discussed under the head "Sources of infection."

The time of appearance of the rot depends upon weather conditions primarily, although it also depends to some extent upon the condition of the fruit and the proximity and number of sources of infection. The fruits of susceptible varieties may be infected even when they are quite young and green, provided the weather is hot and moist and sources of infection are present. On the other hand, some varieties are not easily infected until midseason except under extremely favorable conditions.

Where the sources of infection are particularly abundant, the disease may gain some headway even during seasons in which the weather is relatively unfavorable for its development.

Glomerella cingulata (Stoneman) Spaulding and Von Schrenk, a fungus having an ascogenous, or "perfect," form and a conidial, or "imperfect," form, is the casual organism involved in the production of apple bitter-rot. The most common fruiting stage is the Gloeosporium, or conidial, the so-called "imperfect," stage.

The conidial masses, or acervuli (Pl. I, figs. 4, 5, and 6), when newly formed are pink and mucilaginous or thinly gelatinous. Later, however, upon drying they become dark colored and of a hard, horny consistency. It is through the agency of the conidia that nearly all of the damage to the fruit of the apple is brought about. The gelatinous nature of the conidial masses when wet and their horny consistency when dry prevent the dissemination of the conidia by the wind, but raindrops can spatter them about and especially upon the apples located below infected fruit. Excessive moisture can also cause the conidial masses to trickle or drip down, and here the wind may play a part in modifying the direction of their downward course.

Birds probably play some part in the dissemination of conidia, but a much more important part is played by insects, more especially by flies. Clinton (6) in 1902 first showed that the disease could be disseminated by flies. The writer has often observed flies which, after alighting upon infected fruits and coming in contact with the mucilaginous spore masses, have flown and alighted upon sound apples upon the same and other trees.

As noted by Burrill and Blair (4) in 1902, conidia embedded in the horny mass of the acervulus, if kept dry, retain their vitality during many weeks and even months, but when once suspended in water subsequent drying kills them. These observations have several times been confirmed by the writer.

The ascogenous stage (Pl. I, figs. 1, 2, and 3) is not very easily found in nature or, if found, is rather difficult to identify, owing to the frailness and consequent evanescence of the asci. Clinton (6) in 1902 and Von Schrenk and Spaulding (12) in 1903 succeeded in finding it in diseased fruits and cankers, respectively. The writer has also found this stage in bitter-rot mummies, in cankers caused by the bitter-rot fungus, and in cankers caused by other agencies.

SOURCES OF INFECTION.

MUMMIED FRUITS.

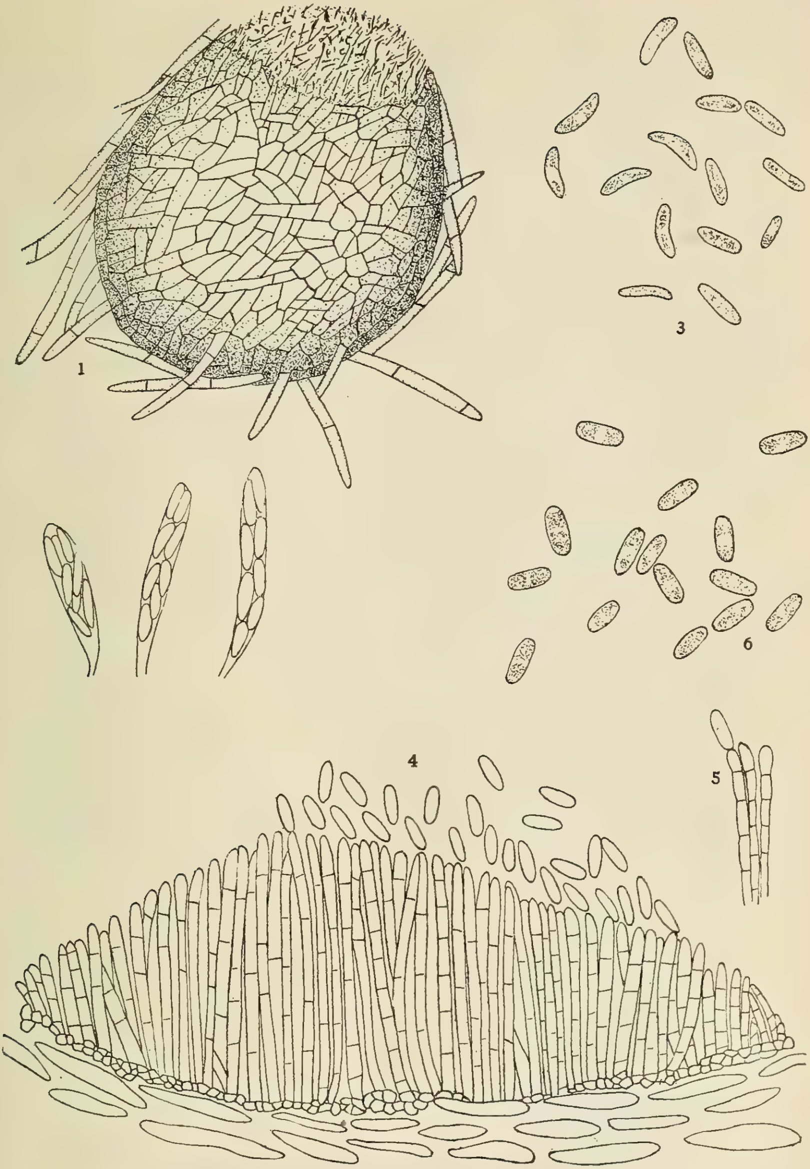
The mummied or rotten fruits which have remained upon the tree or upon the ground since the preceding autumn constitute one of the most important sources for the infection of the fruit of the current year (Pl. II, fig. 1). Often, especially in the eastern United States, they are by far the most important means by which the fungus is carried over from one season to another.

Clinton (6) in 1902 showed that the fungus could live through the winter in mummied fruits. He states—

> However, in the fall and succeeding spring on the mummy apples, the fungus, as a saprophyte, gives rise to the permanent or Gnomoniopsis (Glomerella) spore stage. The Gloeosporium spores that have not been carried away disappear through germination, and more or less of a mat of fungus thread covers the apple. Protected by this, perithecia that develop asci, with ascopores, which evidently came to maturity the next summer, are gradually developed in a stroma. These ascospores are shed out of the asci and perithecia when mature and are then scarcely to be distinguished from the Gloeosporium spores. No doubt they are carried by the pomaceous flies to the green apples and thus start the disease again for another year.

As recorded by Burrill and Blair (4), Hasselbring did not find the second spore forms, described by Clinton, on mummied apples kept out of doors, but he found that the fungus ordinarily retains its vitality in a dormant state in winter, and in May or later under proper conditions begins to produce again the same kind of spores, borne on fertile threads of the fungus, in the same manner as it did the preceding summer. Spores secured from old mummies were inoculated into green apples and produced typical bitter-rot spots. This was repeated with spores from bitter-rot mummies collected in different orchards, and was found to be an easy procedure. Burrill and Blair add—

> The spring infection may therefore start from these old apples, and recent observations in the field have given indisputable evidence that it does sometimes so occur.



MICROSCOPIC CHARACTERS OF THE APPLE BITTER-ROT FUNGUS

FIG. 1.—A perithecium from an artificial culture of *Glomerella cingulata* isolated from a canker caused by *Phyllosticta solitaria*. × 350.

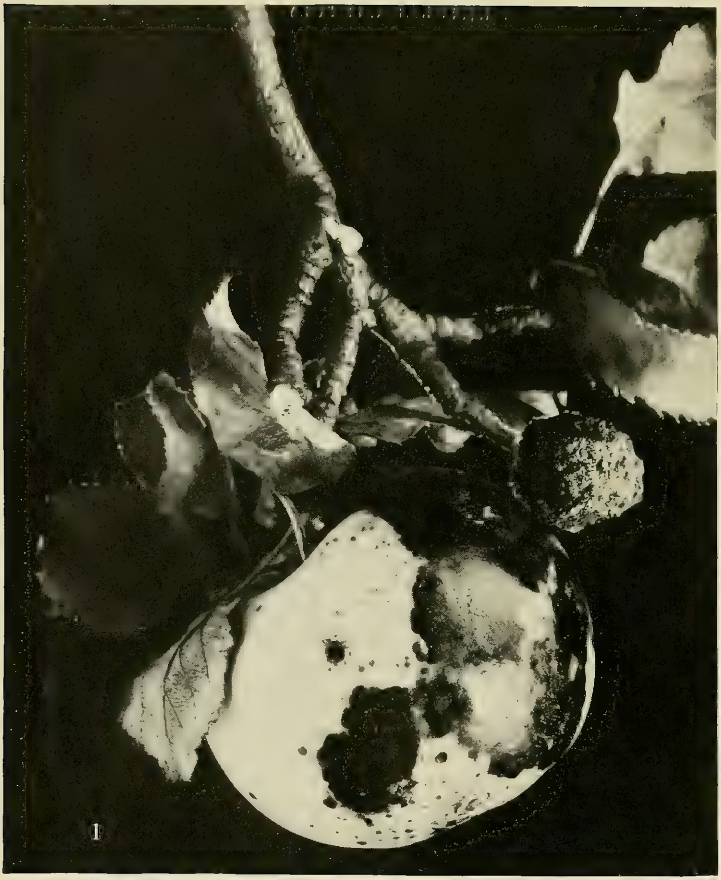
FIG. 2.—Asci from a perithecium obtained in the same manner as that shown in figure 1. × 350.

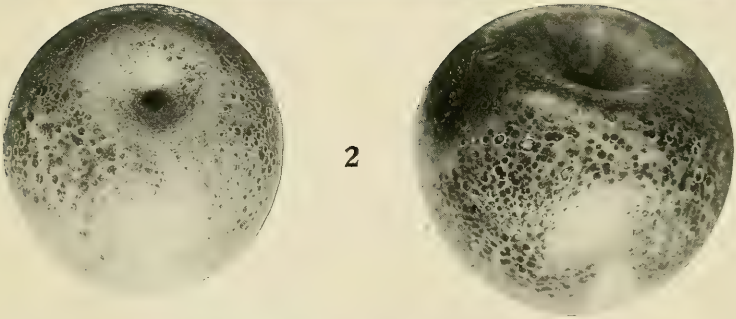
FIG. 3.—Ascospores from asci obtained in the same manner as those shown in figure 2. × 425.

FIG. 4.—Section through an acervulus from a bitter-rot spot on a Ben Davis apple artificially produced through the agency of spores from pure cultures of the fungus. The cultures were made from conidia obtained from a bitter-rot canker. × 350.

FIG. 5.—Conidiophores and a conidium from the acervulus shown in figure 4. × 350.

FIG. 6.—Conidia from the acervulus shown in figure 4. × 425.





APPLES AFFECTED WITH BITTER-ROT.

FIG. 1.—An apple affected with bitter-rot and, just above it, a mummied apple of the preceding season. Spores washed down from the mummy have infected the previously sound apple. Variety, Yellow Newtown. Greenwood, Va., 1916.

FIG. 2.—Apples with the "peppered" appearance caused by many infections. These small blisterlike spots were due to infection by spores coming directly from a bitter-rot canker. Variety, Missouri. Bentonville, Ark., 1914.

Von Schrenk and Spaulding (13) in 1903, after investigations carried on in Missouri, state—

> Another source of infection is found in the dried mummies hanging on the trees and lying on the ground under the trees. The diseased apples of one season either fall to the ground (most of them do) or they remain on the trees, where they dry and shrivel up. When examined in the spring many of these mummified fruits are found to contain spores of the bitter-rot fungus in quantity.

Again they state—

> It was formerly supposed that the fungus passed the winter in the mummies, but as most of these were on the ground it was difficult to understand how the apples high up in the trees became infected. It now seems probable that the mummies play a comparatively small part in serving as distributing points for spores from year to year.

In 1902, Alwood (1), as the result of observations and experiments in Virginia, came to the conclusion that the mummied fruits on the tree and the rotted fruits on the ground were the chief sources of infection. He states—

> It appears to be well established that the mummied fruits hanging to the trees and the rotten fruits upon the soil constitute in large measure the source of the annually recurring infection. To my mind these fruits are *the source* of infection.

Scott (14, p. 12) in 1906, in his discussion of sources of infection, states—

> The results [of observations made in Virginia and West Virginia orchards] lead to the conclusion that the overwintering mummies hanging on the trees constitute the chief source of infection, at least in this particular region. In the majority of cases examined, a mummy could be found in the upper portion of the infected area.

Burrill (3) in 1907 considered that mummies on the ground rarely acted as infection sources.

The writer (10) in 1915, as the results of investigations in the Ozarks of Arkansas, stated—

> Masses of spores were also obtained many times from mummies, and where mummies are present they undoubtedly are important sources of infection. In many of the badly infected orchards, however, they had been removed both from the trees and from the ground.

It will be noted that eastern investigators consider mummied and rotted fruits as the principal means by which the fungus is carried over from season to season. Investigators working in the Middle West, however, consider them as of only secondary importance in the survival of the fungus through the winter.

The writer during the past three years has examined mummied and rotted fruits of previous seasons from orchards in Virginia and in Arkansas. In both mummies and rotted fruits of the preceding year the fungus is usually to be found. However, neither furnished a good medium for the fungus, and as a result the number of spores (usually conidia) produced is quite small compared with the number which the fungus produces when growing in a newly rotted fruit of the current season. The size of the spores is usually somewhat reduced also.

A mummy hanging on a tree furnishes a medium which is deficient in moisture and in plant food. In the case of the rotted apples on the ground the bitter-rot fungus must compete with many of the mold and rot fungi and bacteria which are less susceptible to cold and which are true saprophytes. In examining rotted fruits, one finds a mixture of the spores of the bitter-rot fungus and those of various molds, together with numerous bacteria.

In both Virginia and Arkansas orchards, mummies and rotted fruits undoubtedly are important sources of infection. The writer has examined infected orchards in Arkansas in which bitter-rot mummies and rotted fruits of the preceding year were abundant in the trees and on the ground and in which no other sources of infection could be found. Some of the most seriously infected orchards which the writer has seen, however, were Arkansas orchards from which the mummies and rotted fruit had been removed. Generally, in Arkansas few mummies are to be found in the trees, and as nearly all growers practice clean cultivation throughout the earlier part of the season those which have fallen to the ground have been turned under. It has been a common practice, too, for the grower to gather up and haul to evaporating plants the best of the dropped fruit and to sell the rotten and diseased fruit to the distilleries.

The writer agrees with Alwood and Scott that mummies are the chief sources of infection in the orchards of Virginia. In that State the Yellow Newtown variety, known locally as the Albemarle Pippin, is the commercial variety which is damaged to the greatest extent by the disease. This variety is grown for the most part in coves of the Blue Ridge, situations which usually do not admit of cultivation. These trees do not come into bearing until they are about 15 years old, and they are very long lived. Accordingly, most of them are rather old and quite large. The dropped fruits have no economic value. There are many reasons, therefore, why rotted fruits should be left on the ground. There are usually some mummies also to be found hanging on trees of such size. The writer counted more than a hundred on one tree, which, however, was an unusual number. In Virginia he was easily able to trace the source of clumps of rotted fruits to mummies hanging in the trees. This is readily done if examination is made shortly after the first outbreak of the disease.

In many Virginia orchards the lower limbs when laden with fruit reach to the ground. In such cases the disease could be found first on the fruits in contact with those of the previous season on the ground. From these infected fruits spores could easily be carried to sound ones.

The writer has frequently attempted to find the fungus in mummies and rotted fruits which were more than a year old, but has been uniformly unsuccessful. Those upon the trees appear to be dried up so thoroughly at the end of a year that they drop from the tree; those on the ground finally become almost wholly disintegrated through the action of molds and bacteria.

In Virginia, therefore, mummies and rotted fruits, being more prevalent, are of more importance as sources of infection than they are in Missouri and Arkansas. In the last-named States cankers may overshadow them in importance.

BITTER-ROT CANKERS.

REVIEW OF THE LITERATURE.

In 1902 R. A. Simpson discovered that in Illinois a certain type of canker was associated with outbreaks of bitter-rot. He found that if search was made shortly after the first outbreak of the disease such cankers were to be found just above a clump of infected fruits. Simpson's discovery was announced at about the same time by Burrill and Blair (4) and by Von Schrenk and Spaulding (13).

Burrill and Blair (4) in 1902 stated that Hasselbring had shown the fungus found in these cankers to be identical with the bitter-rot fungus. Hasselbring found that the fungus from the cankers would cause typical bitter-rot when introduced into sound apples.

Von Schrenk and Spaulding (13) in 1903 also showed that spores from the cankers could cause typical bitter-rot when introduced into sound apples. They further showed that spores could be washed from the cankers by water and that when falling upon apples they could produce bitter-rot. To determine whether or not the Glomerella could actually be the causal organism involved in the production of cankers, they inoculated sound branches with spores (conidia) from pure cultures. As a result of these inoculations cankers were formed which showed the characters of the cankers found by Simpson. From these artificial cankers Von Schrenk and Spaulding reisolated the fungus and also inoculated apples with conidia produced in the cankers. They describe the development of the artificially produced cankers as follows:

> Several weeks elapsed before there was any evidence of development on the limbs. In both the inoculated slits and the control slits the bark dried somewhat along the edges of the slit, making a gaping wound. After some

two weeks a distinct callous layer had formed under the edges of the control slits. The two callous layers joined after six to eight weeks and occluded the wound. In the slits where bitter-rot spores had been inserted the callous formation was less marked. The exposed wood turned dark, almost black, and the exposed edges of the bark turned back. The living bark then began to dry out gradually and became depressed, and after about two months a decided, sharply defined depressed area had formed, with the slit in the center. Shortly thereafter small black pustules broke through the dried bark in a number of instances. By that time the infected points showed all the characteristics of small cankers. On examination the black pustules were found to contain masses of spores resembling those of the bitter-rot fungus.

Alwood (1) in 1902, while admitting that cankers may be the chief sources of infection in Illinois and Missouri, as stated by Burrill and Blair (4) and by Von Schrenk and Spaulding (13), did not think that these statements applied in Virginia. He stated—

> In no instance have we been able to find the presence of the bitter-rot fungus on the limbs or trunks of apple or pear, though we have especially watched for its occurrence.

Scott (14) in 1906 made the following statements:

> Limb cankers occur abundantly in Virginia orchards, but the writer has so far been unable to find the bitter-rot fungus associated with any of them . . . in no case was there found associated with such outbreaks any cankers that could be identified as bitter-rot cankers.

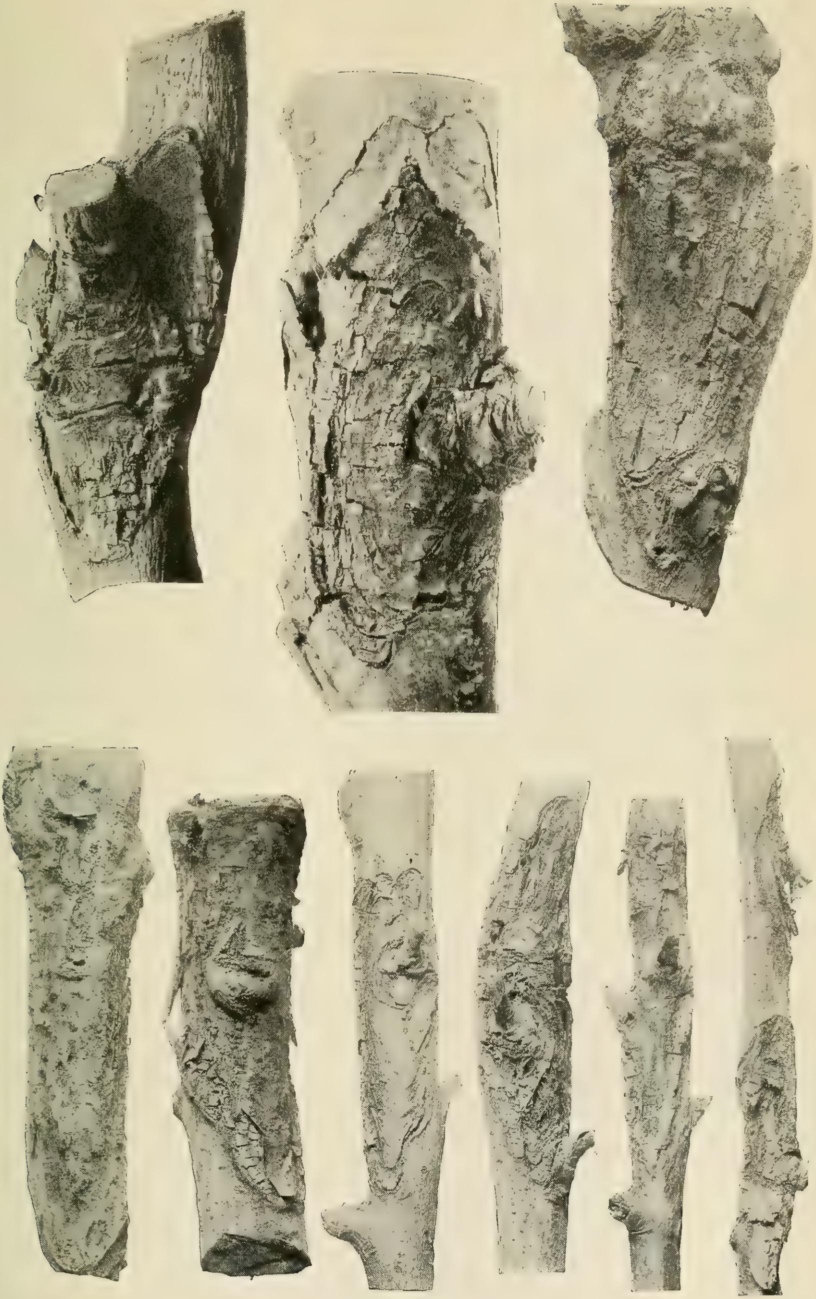
Burrill (3) in 1907 stated that a wound is necessary for the beginning of a canker and that cankers may live sometimes for two or even three years.

The writer (10) in 1915, reporting on work carried on in Arkansas, stated—

> On May 15, a cankered limb from the second orchard was brought into the laboratory and kept in a moist chamber for 24 hours. This canker resembled in every way the limb cankers as described and figured by Burrill and Blair and Von Schrenk and Spaulding. It was a black, sunken oval area with many slight rifts or cracks in the bark through which, after the limb had remained in a moist chamber for 24 hours, an abundance of the characteristic pink acervuli appeared. Near the center of this canker was a small dead spur through which infection probably took place. Cankers resembling in every way published descriptions and figures of bitter-rot were also collected on June 3 and many times thereafter.

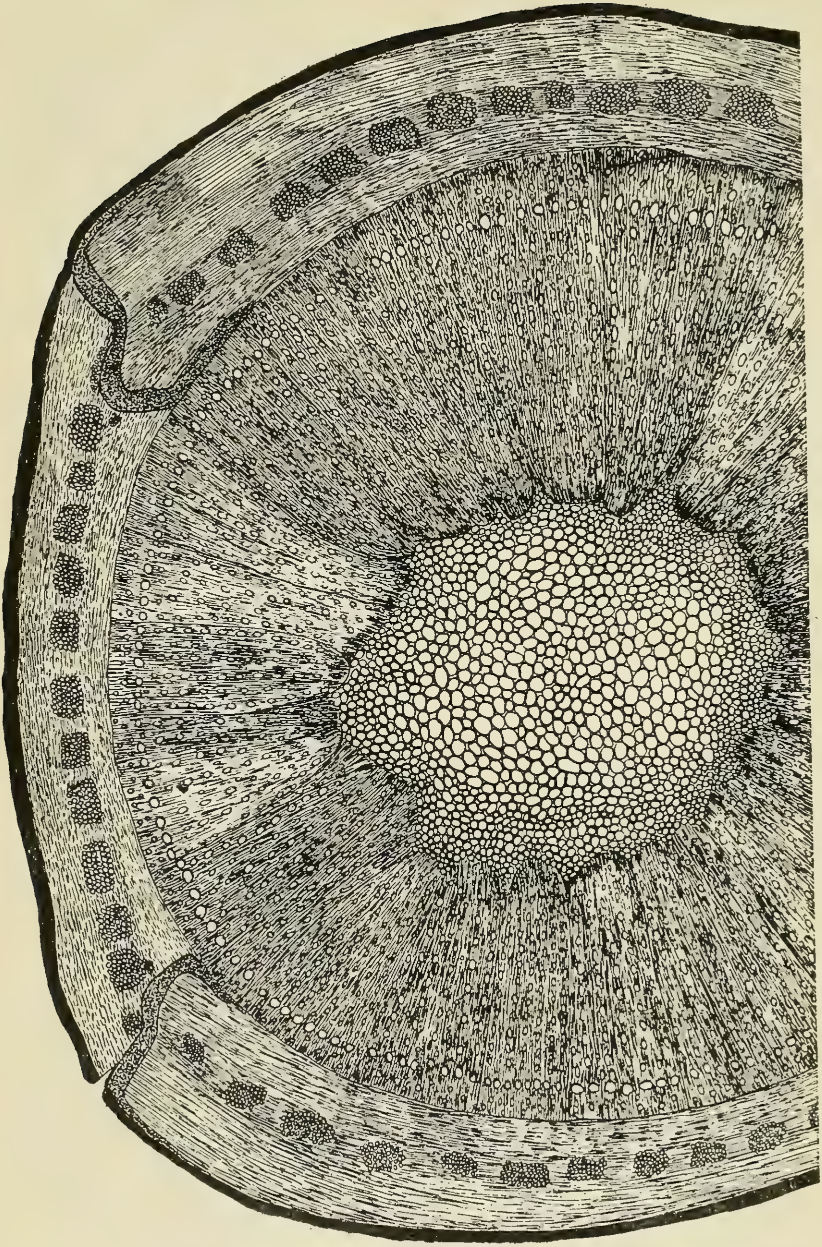
Previous to his experiences with bitter-rot cankers in Arkansas, the writer had attempted at various times to find them in Virginia, but without success. Thinking that his familiarity with the appearance of the cankers in the West might aid him in the search, he again attempted to find them in Virginia in 1916 but was unsuccessful.

It seems therefore rather well demonstrated that whereas bitter-rot cankers are of quite common occurrence in the Middle West, they are rarely to be found or are wholly wanting in the East. The



BITTER-ROT CANKERS ON APPLE BRANCHES OF VARIOUS AGES.

Each of these cankers was located above a clump of rotted fruits and was producing spores in immense numbers. The varieties are Givens, Jonathan, and Ben Davis. Bentonville, Ark., 1915.



SECTION THROUGH A BITTER-ROT CANKER ARTIFICIALLY PRODUCED ON A YOUNG BRANCH OF A BEN DAVIS APPLE TREE.

The reaction of the host is shown in the formation of a callus layer. The dead bark remains attached to the dead and shrunken wood. × 32.

writer is unable to find a record of a bitter-rot canker occurring in eastern orchards.

DESCRIPTION OF CANKERS.

The cankers caused by *Glomerella cingulata* (Pl. III) are fairly characteristic and are not easily confused with any other cankers except those caused by the pear-blight organism (*Bacillus amylovorus*). Especially on varieties which have suffered severely from pear blight, bitter-rot cankers and pear-blight cankers are sometimes hard to differentiate. The writer does not doubt that in the past bitter-rot cankers have many times been mistaken for pear-blight cankers.

The bitter-rot canker consists of a sunken portion of bark, usually somewhat oval in outline, beneath which the wood is dead and dry. The dead bark and cambium adhere rather firmly to the wood, and in older cankers more or less complete cracks or fissures parallel to the edges of the cankers give a zoned effect to the dead bark. The depression (Pl. IV), too, in older cankers becomes much more pronounced, owing to the fact that because of the death of the cambium there has been no increase in the thickness of the branch in the infected area. The wood and medullary rays, even in the case of young cankers, are colored brown all the way into the pith. Often the canker is surrounded by a layer of callus (Pl. IV), which successfully prevents further extension of the canker and which eventually entirely obliterates the old lesion.

In many cankers a small dead twig will be found directly in the center of the blackened area, doubtless explaining the mode of entrance of the fungus. Sometimes this dead twig is the remains of a fruit spur, but often it is a water sprout, part of which has been broken off.

Cankers are usually found on branches which are at least 2 years of age. The writer has found them on branches which range in age from 2 to about 15 years, but has never been able to find them on young vigorously growing twigs less than 2 years of age.

The number of cankers per tree is usually few, even in orchards in which the disease has been very serious for a number of years. However, in the case of especially susceptible varieties, such as Givens, the writer has found trees having more than 30 large bitter-rot cankers, besides numerous small ones.

At first thought it would seem that cankers, being located on older branches and hence near the center of the tree, are not advantageously located for the infection of fruits, but as the apples develop and bend the branches downward the position of the cankers is often directly above that of large numbers of the apples. Plate II, figure 2, shows young fruits badly infected from cankers thus located.

LIFE HISTORY.

In the literature pertaining to bitter-rot cankers there is very little to be found on the subject of their development and length of life. Spaulding and Von Schrenk (13) state—

> The majority of the cankers found during the last summer probably were started two years ago. During the first year the fungus made very little headway. A very small central area was killed, generally around and including a small branch. The following year the large part of the canker was formed. Whether the cankers will continue to increase in size is as yet undetermined, but it does not seem probable, for if such were the case cankers 3 or more years old ought to have been secured in the orchards where the bitter-rot has been common for many years.

On many varieties the writer has not been able to find any very old cankers, but in the case of very susceptible varieties, such as Givens, he has found many cankers which have attained apparent ages of 8, 10, and more years. One limb, which by count of annual rings was 13 years old, bore a canker which showed 11 zones, indicating that the canker had passed through 11 growing seasons. Cankers were found growing on main limbs which were evidently much older than this. In order to trace the development of cankers, the writer in 1914 made some preliminary inoculations of apple branches with spores from pure cultures of *Glomerella cingulata*. Inoculations were made by introducing newly formed conidia into small slits artificially made in the bark. The slits were at once covered with absorbent cotton moistened with distilled water, which was allowed to remain for one week. Controls consisted of branches similarly treated except that no conidia were placed in the slits.

In Arkansas on September 14, 1914, the following inoculations and control experiments were made, using as inoculum conidia from corn-meal cultures of the fungus isolated from a canker on August 3:

Three inoculations in slits in 2-year-old branches.
One control slit in a 2-year-old branch.
One inoculation in a slit in a 1-year-old branch.
One control slit in a 1-year-old branch.

The tree used was a 15-year-old specimen of the Missouri variety. The weather had been hot and moist and accordingly was quite favorable for the development of the fungus.

When the absorbent cotton was removed one week later it was evident that the inoculations had been successful. About the slits into which the conidia had been introduced the bark was blackened and sunken in a ring from 1 to 2 mm. in width, whereas only the cut surfaces of control slits were blackened. By October 7 the inoculated slits formed the central portions of rapidly growing cankers. At that time the fungus on the 2-year-old branches had developed until the blackened, sunken areas had attained lengths varying from

2 to 5 cm. and widths varying from 1 to 1.5 cm. The growth from the inoculation in the 1-year branch was even greater, the dead area being nearly 6 cm. in length. The control slits were beginning to heal.

On account of the writer's absence from Arkansas, the inoculated branches were not again examined until April 1, 1915. At that time the inoculated slit and control slit on 1-year-old twigs were not to be found, the twigs having been removed when the trees were pruned in March. The remaining cankers were the same size and apparently in the same condition as in the preceding autumn. The blackened bark presented the same sunken appearance and was still joined to the bark of the adjacent apparently healthy portions of the branch.

By May 10 there was no change in the general appearance of the cankers except that the blackened bark was no longer connected with the adjacent uninjured bark. There was a distinct fissure running entirely about the cankers, separating the blackened bark from the adjacent bark except at the extreme ends of the cankered area. This isolation of the dead bark was undoubtedly due to the fact that the branch had resumed growth, whereas the fungus had not. By May 21 the delimiting fissure was more pronounced, though the blackened bark was not wholly isolated. On this date the cankered branches were cut off, brought into the laboratory, and placed in moist chambers. At the end of 24 hours acervuli of the fungus appeared in all three of the cankers. Cultures from the conidia showed all the characters of *Glomerella cingulata*. Three of these cankers and one control were photographed and are shown in Plate V, figures 1, 2, and 3.

Another series of inoculations was made in Arkansas on June 18, 1915. The same technique was employed as in the experiments of 1914. The spores used in the inoculations were ascospores from cultures made from a canker on June 4 and conidia from cultures made from a canker on May 21. The plan of the experiment was as follows:

Three slits were inoculated with ascospores.
Three slits were inoculated with conidia.
Three slits were not inoculated.

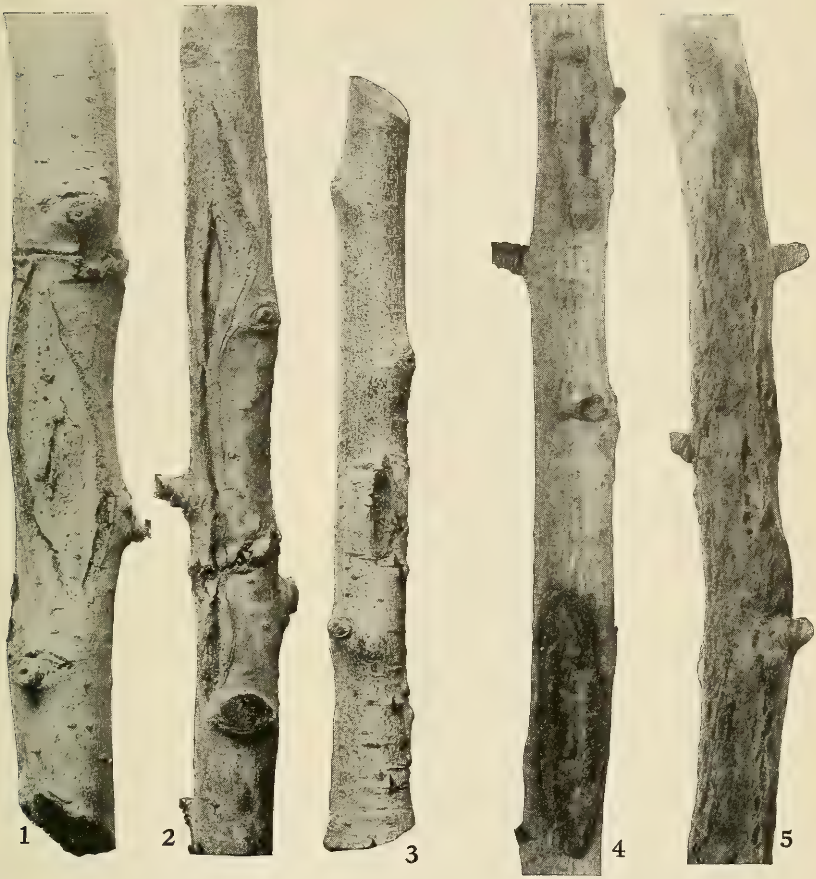
This plan was carried out on three varieties—Ben Davis, Jonathan, and Missouri. The moistened cotton covering the slits was removed on June 23. Only 2-year-old branches were employed. The weather was cool and accordingly not very favorable to the growth of the fungus.

On July 8 all of the control slits were beginning to heal. In the case of the Ben Davis there was a band of dark sunken bark extending a distance of 2 mm. about each inoculated slit. About the slits on the Missouri branches the dark sunken band was 3 to 4 mm. in width. There was no development whatsoever in the case of the Jonathan, either at this time or subsequently. On August 30 the black sunken bands about the slits on the Ben Davis branches were from 2 to 6 mm. in width, while those on the Missouri branches were slightly larger. The inoculated branches were not examined again until June 18, 1916. The cankers had not changed perceptibly. The chief thing to be noted was that there was no isolation of the blackened bark on three of the Ben Davis branches and on three of the Missouri branches. These branches, though of equal age, were not nearly so large as the others, which were rapidly growing water sprouts. The cankered areas on the water sprouts were being rapidly healed over by the formation of callus, and the blackened bark had been partly shed. The cankered branches were removed, brought to the laboratory, and placed in moist chamber for 24 hours. Acervuli of the fungus were produced in great abundance, and when reisolated in pure culture the organism was reidentified as *Glomerella cingulata.*

The question arises as to why quickly developing young cankers on vigorous young branches and water sprouts should not live and develop through the following season. Apparently this is what happens: The host has its period of most rapid growth in the spring. In the case of young branches and water sprouts, growth is particularly rapid at this time. The fungus, on the other hand, does not begin active growth until hot weather begins. Vigorously growing branches, such as water sprouts and young twigs, are able, therefore, through the growth of surrounding tissues to utterly isolate the young cankers and begin the formation of callus at their margins while the fungus is still dormant.

To test the effect of cool weather and to see if late infections would develop, Ben Davis and York Imperial branches were inoculated at Arlington Farm, Va., on October 5, 1915. The weather, though cool, was moist, but no perceptible growth was made about any of the 12 inoculated slits, nor was any growth made during 1916. On the contrary, the slits had entirely healed over by July 1, 1916.

Employing the same methods as in 1914 and 1915, the writer made several series of inoculations at Arlington Farm, Va., in 1906, using cultures of the fungus from a canker collected in Arkansas during the preceding autumn. In Table I the terms "margin intact" and "margin cracked" mean in the former case that the blackened bark of the canker is continuous with that of the uninfected portion of the branch and in the latter that it has been broken away from the bark of the uninfected portion. No separate notes were made concerning individual inoculations on the same limb, for the reason



APPLE BRANCHES SHOWING ARTIFICIALLY PRODUCED BITTER-ROT CANKERS AND ONE USED AS A CONTROL.

FIGS. 1 and 2.—Branches showing bitter-rot cankers artificially produced. Inoculations made through slits September 14, 1914. Removed and photographed May 27, 1915. Variety, Missouri. Bentonville, Ark.

FIG. 3.—A branch showing a control slit in the series of inoculations made September 14, 1914. Removed and photographed May 27, 1915. Variety, Missouri. Bentonville, Ark. For inoculated slits, see figures 1 and 2.

FIGS. 4 and 5.—Branches showing bitter-rot cankers artificially produced. Inoculated through slits July 13, 1916. Removed and photographed January 9, 1917. Figure 4, variety, Winesap; figure 5, variety, Jonathan. Note the large size of the cankers shown in figure 5.

that the resulting cankers usually showed no differences in their development.

Types of the cankers produced on the Winesap and Jonathan varieties are shown in Plate V, figures 4 and 5.

TABLE I.—*Results of inoculations of apple branches with bitter-rot fungus cultures at Arlington Farm, Va., in 1916.*

Apple variety and date of inoculation.	Age of branch.	Number of inoculated slits.	Width of blackened band.		Condition.	
			On Aug. 2.	On Aug. 29.	On Aug. 29.	On Nov. 20.
Ben Davis:	*Years.*		*Mm.*	*Mm.*		
June 28	4	3	3	3	Margins intact	Margins intact.
Do	4	3	2 to 5	5	do	Do.
Do	1	3	5 to 13	5 to 13	do	Margins cracked.
July 13	4	2	3	5	do	Margins intact.
Do	2	2	1 to 5	1 to 8	do	Do.
Do	3	2	4	5	do	Do.
York Imperial:						
June 28	1	4	1 to 5	1 to 5	Margins cracked	Margins cracked; callus formed.
Do	1	4	1 to 3	1 to 3	do	Do.
July 13	4	2	0	0	Healing	Healed.
Do	2	2	0	0	do	Do.
Do	4	2	0 to 1	....	do	Do.
Missouri:						
June 28	1	4	4 to 10	4 to 10	Margins intact	Margins nearly intact.
Do	1	4	0	0	Healing	Healed.
Do	3	4	0 to 1	....	do	Healing.
July 13	1	2	4	4	Margins intact	Margins nearly intact.
Do	4	2	3 to 5	8 to 10	....	Margins intact.
Do	4	2	15	15	....	Do.
Jonathan:						
June 28	1	4	0	0	Healing	Healed.
Do	1	4	0	0	do	Do.
Do	5	4	2 to 15	2 to 15	Margins intact	Margins intact.
July 13	4	2	30	30	do	Margins nearly intact.
Do	3	2	40 to 45	40 to 45	do	Do
Do	3	2	15 to 20	15 to 20	do	Do.
Grimes:						
June 28	1	5	1	1	Margins cracked	Healed.
Do	2	5	0 to 1	0 to 1	do	Do.
July 13	4	2	15	15	do	Margins cracked.
Do	4	2	2 to 15	2 to 15	do	Do.
Do	3	2	10	10	do	Do.
Winesap:						
June 28	4	5	2 to 15	2 to 15	do	Do.
Do	3	5	0	0	do	Healed.
July 13	4	2	5 to 10	5 to 10	do	Margins cracked.
Do	4	2	4 to 5	4 to 5	do	Do.
Do	4	2	30	30	do	Margins somewhat cracked.
Yellow Newtown:						
June 28	1	4	2	2	Healing	Healed.
Do	1	4	1	1	do	Do.
July 13	3	2	2	2	Margins cracked	Margins cracked; healing.
Do	2	2	2	2	do	Do.
Do	3	2	3	3	do	Do.

The following general notes on all the inoculations were made on November 20, 1916, and on January 9, 1917:

Ben Davis.—Except in the case of the 1-year-old branches, the margins of cankers are intact.

York Imperial.—Margins of cankered areas are separated from the bark of living portion of branch, and callus is forming.

Missouri.—Margins of cankers are intact except in the cases of very young branches (water sprouts).

Jonathan.—Cankers are very large on older branches, with small amount of cracking at margin.

Grimes.—Cankers have margins cracked; probably will survive.

Winesap.—Margins of cankers are somewhat cracked and much roughened; probably will not survive.

Yellow Newtown.—Margins of cankered areas are separated from bark of living portion of branch, and callus is forming.

On June 26, 1917, the following notes were taken:

Ben Davis.—Cankered areas irregularly cracked at margins in case of younger limbs. Layers of callus are forming. Those on older wood have margins intact. Acervuli are abundant.

York Imperial.—Slits have healed over. They are similar to the control slits.

Missouri.—Margins are irregularly cracked at the sides but not at the ends of the cankers. The cracks are not quite so large as in case of the Jonathan variety.

Jonathan.—Margins are cracked at the sides and separated from the living bark, from which callus is forming. There is no such separation, however, at the ends of the cankered areas.

Grimes.—Margins are cracked and a callus layer is forming. Acervuli are abundant.

Winesap.—The same as Grimes.

Yellow Newtown.—Lips of callus nearly meet. The dead bark is nearly all shed. The remnants of the old dead bark, however, produced acervuli and spores after 48 hours in moist chamber. The acervuli were very small and the spores few.

By September 19, 1917, the slits on the York Imperial and Yellow Newtown were healed over and the dead cankered bark completely eliminated. The cankers on the Ben Davis were persisting without any apparent change. In the case of the Missouri and the Jonathan varieties there was little or no new growth. Layers of callus were forming, but the old cankers with their dead bark still persisted. The former large lesions on the Grimes were nearly healed over, with elimination of most of the old dead bark. The lips of the layers of callus were nearly meeting. The Winesap cankers were similar to those of the Grimes except that the healing process had not been quite so rapid and hence more dead bark remained. In the case of all varieties except the York Imperial and Yellow Newtown, the fruit below the cankered limbs was infected with bitter-rot. The infected areas extended to the lowest limbs and were about 6 feet across. The infection was not carried to the fruit of adjacent trees, only the fruit of trees in which cankers had been artificially produced being affected. This shows how restricted is the dissemination of the disease and why it may become localized in certain trees.

As a result of these experiments it appears that the Ben Davis, Missouri, and Jonathan varieties are quite susceptible to the canker disease. The Grimes is apparently not quite so susceptible, but is more so than the Winesap. The York Imperial and Yellow Newtown are very nearly immune. While on the two last-named varieties the fungus may begin the development of a canker, the reaction of the host is such that the growth of the fungus is soon checked and the incipient canker itself is later obliterated by the formation of callus. As these two varieties are the ones chiefly found in Virginia orchards and as their fruits, especially those of the Yellow Newtown, are susceptible, the writer believes that these inoculation experiments explain why bitter-rot cankers have not been found in that State.

It is also worthy of note that in these experiments the inoculations were eventually more successful on older branches than on 1-year-old twigs and water sprouts, though the growth was usually slower on the older branches. This is in accord with the writer's observations on naturally formed bitter-rot cankers.

The inoculations made in July were more uniformly successful than those made in June, doubtless owing to the fact that in July the temperature was much higher and the growth of the host more restricted.

These experiments and the writer's observations indicate that cankers in which the growth of the fungus is comparatively slow are apt to be much longer lived than those in which the fungus develops rapidly. This is particularly true in the case of the Givens, a variety which harbors more cankers than any with which the writer has come in contact. Cankers on Givens branches grow very slowly, but are exceedingly persistent.

Young vigorous-growing twigs are able, after the hot season which favors the bitter-rot fungus is over, to continue growth and by the formation of a callus layer to utterly isolate the mycelium of the fungus in the tissues which it has killed. This explains why the writer has not been able to find bitter-rot cankers on young branches.

It seems probable that another reason why cankers on branches of the Givens variety are so persistent is that this variety begins growth in the spring nearly two weeks later than most varieties. It is in the spring that the most vigorous growth of the apple occurs, and hence it is at this time of year than the branch is in the best condition to isolate the cankered areas and develop callus. The fungus, on the contrary, is not able to start growth until the weather becomes hot. This conclusion is drawn from the inoculation experiments of 1914 and 1915.

On January 9, 1917, three cankered branches of each variety inoculated in the 1916 experiments were cut off, brought into the laboratory, and placed in moist chambers for 48 hours. Masses of spores were produced from all cankers except those from the York Imperial and Yellow Newton trees. Cankers on the branches of these two varieties were nearly healed over, and in the dead bark remaining the fungus was no longer alive.

Although these experiments seemed to show rather conclusively that the branches of the Yellow Newtown, the chief commercial apple whose fruit is susceptible to bitter-rot in Virginia, are resistant to the disease, it was also thought possible that the fungus found in Virginia might not be capable of causing cankers. This, however, proved not to be the case, as is shown by the series of inoculations listed in Table II. In fact, in these experiments the fungus isolated from Virginia fruits attacked the branches more vigorously than that isolated from bitter-rot cankers from Arkansas. The results of these inoculations did not differ materially from those of the previous experiments.

TABLE II.—*Comparison of results of inoculations of apple branches with bitter-rot fungus cultures from fruits grown in Virginia and in Arkansas, at Arlington Farm, Va., on August 21, 1916.*

Source of culture used.	Apple variety.	Age of branch.	Number of inoculated slits.	Width of blackened band.	
				On Aug. 29.	On Sept. 15.
		Years.		*Mm.*	*Mm.*
Virginia fruit	Ben Davis	2	6	1	6 to 20
Arkansas canker	do	3	6	1	1 to 2
Do	do	2	6	0	0
Virginia fruit	Missouri	2	4	2 to 3	3 to 10
Do	do	4	4	1	4 to 10
Arkansas canker	do	2	4	0 to 2	0 to 5
Virginia fruit	Yellow Newtown	1	4	1	4

The importance of cankers as sources of infection is also greatly increased by the enormous number of spores which a single canker is capable of producing in a season. The writer estimated that the number of conidia in one canker 7 cm. long by 2 cm. wide, not a large specimen by any means, was not less than nine millions. When one considers that during moist hot weather the production of spores may be almost continuous, he realizes that the number produced from a single canker during one season must be enormous.

SUMMARY OF KNOWLEDGE REGARDING BITTER-ROT CANKERS.

Knowledge of the bitter-rot cankers may be summarized as follows:

(1) Discovered by Simpson in 1902 and shown by Spaulding and Von Schrenk, in 1906, to be due to *Glomerella cingulata*.

(2) May occur perennially on older branches of susceptible varieties and may survive many years.

(3) Infections on younger branches develop rapidly but do not survive.

(4) Slow-growing cankers are more apt to survive.

(5) Varieties differ in susceptibility to the canker disease; the Yellow Newtown and York Imperial are nearly immune.

Since bitter-rot mummies and bitter-rot cankers are the chief starting points of the disease for the current season, a comparison between them as sources of infection is of interest. (Table III.)

TABLE III.—*Comparison of cankers and mummies as sources of infection.*

Cankers.	Mummies.
Relatively few except on very susceptible varieties..	May be few or many.
Spores produced in great quantity....................	Spores relatively few, owing to mummies being a poor culture medium.
A more or less perennial source......................	An annual source.
Directly injurious to the tree.......................	Not injurious to the tree directly.
Fungus comparatively well protected from competition with other organisms.	Fungus not well protected.
Relatively hard to find and remove...................	Rather easily found and removed.
Located on older twigs or branches (not so advantageous).	Located among next year's fruits (advantageous).

CANKERS OTHER THAN THOSE OF BITTER-ROT.

In 1915 the writer (10) as the result of some work carried on in Arkansas in 1914, showed that the bitter-rot fungus may survive the winter in almost any cankered or dead part of an apple tree, including Illinois apple-tree cankers due to *Nummularia discreta*, dead tips of fruit spurs, dead parts of limbs injured by freezing or death of roots, branches injured by mechanical means, cankers caused by the pear-blight organism (*Bacillus amylovorus*), and twig cankers caused by the apple-blotch fungus (*Phyllosticta solitaria*).

In the case of those Arkansas and southern Missouri orchards in which the disease has been especially destructive over a period of years, it is comparatively easy to isolate the fungus from almost any dead portion of the trees. Such orchards which may have in addition bitter-rot cankers and bitter-rot mummies show how extremely destructive the disease can be and how very important are the agencies which carry it over from season to season. The fruit of orchards in which so many sources of infection survive the winter may be utterly ruined at the very first outbreak of the disease. These cases are, of course, exceptional ones; yet the writer has seen orchards the crops of which were totally ruined within a week, each apple averaging approximately 500 infections. In such cases, in which infection from wintering-over sources is so heavy, control by spraying alone is impossible.

Cankers due to various causes are important sources of infection in the Middle West, but they appear to play very little part in the infection of fruit in eastern orchards. The writer has found comparatively few cankers of any sort in eastern orchards susceptible to bitter-rot, and from those which he has found he has never been able to isolate the bitter-rot fungus. Pear-blight cankers from Yellow Newtown trees whose fruit had been badly damaged by the disease failed to produce fruiting bodies of *Glomerella cingulata.*

Blighted limbs of the Ben Davis, York Imperial, Missouri, Jonathan, Grimes, Winesap, and Yellow Newtown at Arlington Farm, Va., were sprayed on July 18, 1916, with a suspension of conidia in distilled water. Three branches of each variety were thus sprayed. On August 8 the branches were removed and placed in moist chambers. On August 10 sparsely fruiting acervuli were found on one branch each of Grimes, Jonathan, and Missouri; no signs of the fungus could be found on the remaining 18 branches.

LEAVES.

While leaves are of little importance as sources of infection and the writer has never found the fungus fruiting on them naturally, they are able to act at times as harboring places for the fungus.

Leaves of the Yellow Newtown from Virginia, even when in apparent health, will often develop acervuli of the fungus if kept in a moist chamber for a period of 12 to 36 hours, the leaves themselves becoming dark brown. In Arkansas, however, the writer was never able to find the fungus in the leaves of any of the varieties examined, namely, the Givens, Ben Davis, and Missouri.

Shear and Wood (15) in 1913 found that leaves of various hosts treated as above developed the fruiting bodies of the fungus. They state—

> From these and numerous other experiments of a similar kind performed at different times during the year with leaves from other plants, it appears that this fungus is quite generally present in the leaves of many plants in a dormant or innocuous condition awaiting some weakening of the host or other favorable condition which may give it an opportunity to develop.

The writer has many times during the spring and early summer examined the fallen leaves of the preceding year in an effort to find the fungus either fruiting on their surfaces or living within their tissues. Such efforts, however, have been uniformly unsuccessful. It is possible that the fungus, not being able to gain much headway in the living leaf on account of the vitality of the leaf itself, is kept from further development after the death of the leaf by the coolness of the weather prevalent at that time. Bacteria and molds not so sensitive to the cold may enter, however, and deprive the bitter-rot fungus of the food necessary for its existence and further development during the following season, even should it survive the winter in a dormant stage.

OTHER HOST PLANTS.

Shear and Wood (15) in 1913, after careful cultural and morphological studies in addition to cross-inoculation work with cultures from various hosts, gave the following list of 34 plants liable to attack by *Glomerella cingulata* (Stoneman) S. and V. S.

Brya ebenus (L.) DC. (Jamaica ebony.)
Caryota rumphiana Mart. (Palm.)
Cinnamomum zeylanicum Nees. (Cinnamon.)
Citrus aurantium sinensis L. (Sweet orange.)
Citrus decumana (L.) Murr. (Pomelo.)
Citrus limonum Risso. (Lemon.)
Citrus nobilis Lour. (Mandarin.)
Coffea arabica L. (Coffee.)
Costus speciosus (Koenig) Smith. (Spiral flag.)
Curculigo sp.
Eriobotrya japonica (Thunb.) Lindl. (Loquat.)
Ficus carica L. (Fig.)
Ficus elastica Roxb.. (Rubber plant.)
Ficus longifolia Schott.
Ginkgo biloba L.
Gleditsia triacanthos L. (Honey locust.)
Hedyscepe sp. = Kenita. (Palm.)
Ligustrum vulgare L. (Privet.)
Malus sylvestris Mill. (Apple.)
Mangifera sp. (Mango.)
Maranta arundinacea L. (?) (Arrowroot.)
Oxycoccus macrocarpus (Ait.) Pers. (Cranberry.)
Persea gratissima Gaertn. f. (Avocado.)
Phormium tenax Forst.
Pimenta acris (Swartz) Jostel.
Piper macrophyllum Swartz. (Pepperwort.)
Pitcairnia corallina Linden.
Psidium guajava L. (Guava.)
Ribes oxyacanthoides L. (Gooseberry.)
Rubus occidentalis L. (Black raspberry.)
Thea japonica (L.) Baill. (Camellia.)
Thea sinensis L. (Tea.)
Theobroma cacao L. (Chocolate nut.)
Vitis labrusca L. (Concord grape.)
Annona cherimola Miller. (Cherimoya.)
Crataegus sp. (Hawthorn.)
Rubus trivialis (cult.). (White dewberry.)
Smilax medica Schl. and Cham.
Vanilla planifolia Andrews. (Vanilla.)

Taubenhaus (17) in 1914 expressed the belief that *Gloeosporium officinale* E. and E., which he found caused a disease of the spicebush (*Benzoin aestivale* (L.) Nees) and of sassafras (*Sassafras variifolium* (Salisb.) Ktze.) in Delaware, is identical with the fungus which causes apple bitter-rot. He based his belief upon the fact that apples inoculated with the organism from the spicebush and sassafras developed the characteristic bitter-rot. He recommends the extermination of both the spicebush and the sassafras, so as to prevent them from harboring the bitter-rot fungus and carrying it to the apple.

The writer was never able to find the bitter-rot fungus on sassafras in Arkansas, though sassafras is very abundant in that section of the country. It is rather common, in fact, to find orchards surrounded by hedges of sassafras which have escaped destruction because of their nearness to the wire fences inclosing the orchards.

None of these plants as sources of infection compare in importance with mummied apples, apple cankers, or diseased apples. On none of these hosts, such as sassafras, raspberry, or hawthorn, which are commonly found in close proximity to orchards, does the disease become very destructive or epiphytotic, as it does upon the apple. Furthermore, since the agency of birds or insects would be required for the infection of apples from such sources, only a few isolated fruits would probably be infected. Thus, while plants other than the apple would not be very important sources of infection in so far as the current year's fruit is concerned, provided the grower exercises ordinary watchfulness, they are of importance in that they may be a means of introducing the disease into an orchard which previously had been free from it and in which it may increase and eventually become very destructive.

In addition to those mentioned above, the fungus also occurs on the pear, apricot, tomato, sweet pea, and other plants, according to Halstead (8), Chester (5), and Sheldon (16).

INFECTED FRUITS OF THE CURRENT YEAR.

From the primary sources of infection previously discussed, especially mummies and cankers, the fruits of the current year become infected. These in turn become of the greatest importance as secondary sources of infection just as soon as acervuli begin to be produced in the diseased spots.

While the sources of infection, mummies, cankers, etc., which carry the disease over from season to season are of prime importance in that they initiate the disease, nevertheless, except in occasional orchards in which they are so prevalent as to be able to infect nearly every apple at the outset, the infected fruits of the current season are most important in the subsequent spread of the disease.

When the infected spot becomes a few millimeters in diameter, acervuli begin to form, and in a few days, if weather conditions are favorable, spores by the thousand may be washed down upon the sound fruits below. Thus a few infected apples may soon infect the entire crop of a tree.

When one considers that each infected apple becomes after a few days a new source of infection, and that the fungus grows and fruits very rapidly, he will have little difficulty in understanding why the disease can destroy an apple crop so quickly and will comprehend why it is so important that the application of spray for the control of the disease should be made before the first appearance of the disease. After the disease has become well established, attempts to control it by spraying not supplemented by the removal of infected fruits are usually ineffective if subsequent weather conditions are at all favorable to the development of the bitter-rot.

Often only a very few trees in an orchard will possess cankers and mummies in which the fungus has survived the winter. The fruit of these trees, then, is the first to become infected. From these infected apples the disease may be transmitted to the fruit of surrounding trees.

The transmission of the disease from susceptible varieties to rather resistant varieties may also occur through the medium of spores from infected fruits. Such destruction of the fruit of varieties normally resistant often occurs during years in which the weather conditions particularly favor the disease, especially if the trees are located in close proximity to susceptible varieties.

RELATION TO CONTROL MEASURES.

Under ordinary circumstances and in the average orchard, even in sections in which bitter-rot is an especially serious disease, control may be attained by means of spraying alone; but there are some orchards in which the wintering-over or primary sources of infection are so abundant that frequent sprayings, even if most carefully and thoroughly done, will not give adequate control.

The writer (10) in 1914 carried on control experiments in two orchards of this type in Arkansas and published his results in 1915. Both of these orchards had sustained in previous years heavy losses—from 20 to 50 per cent of the crop—in spite of frequent and thorough sprayings with Bordeaux mixture. The removal of mummies, cankers, and deadwood, supplemented by spraying, proved to be an efficient control measure and was so reported.

One of the orchards selected for the 1914 work was again used for the experiments of 1915. This orchard, consisting of about 400 trees, was given its regular annual pruning in March, and the pruners were instructed to pay special attention to the cutting out of all cankers and deadwood.

After the pruning was completed the orchard was again carefully examined and all cankers and deadwood which could be found removed. The pruners had done their work so well that few cankers and little deadwood could be found, though, of course, it was realized that to remove every canker and bit of deadwood was impossible.

The trees were sprayed with Bordeaux mixture on June 15. The disease became evident about July 15, and on July 19 small clumps of rotted fruits could be seen on many of the trees. On the last-named date the writer, with three helpers, picked off all the rotted fruits that could be found, in order to prevent their serving as sources of infection for the sound fruit remaining. The clumps of rotted fruits also served as indicators as to the location of the original sources of infection, which, when found, were removed. In this way many cankers of various sizes which had been missed at pruning time were removed. In fact, it may be said that this constituted practically a final clearing out of the sources of infection which had lived over from the previous season. In the case of three trees the percentage of infected fruit was so large that the entire crop was shaken off. One tree, which appeared to be hopeless on account of the number of cankers and was otherwise of small value, was left untouched and recommended for removal.

As soon as a few of the trees were free from rotted fruit the spray outfit was started, so that each tree was sprayed almost as soon as the diseased fruits, mummies, and cankers were removed. This treatment so effectually checked the spread of the disease that comparatively few new infections occurred, although the season was an exceedingly favorable one for the development of the rot, the loss on many near-by orchards being 25 per cent and upward. The trees were again sprayed with Bordeaux mixture on August 7.

The varieties used in this experiment were the Jonathan, Ben Davis, and Givens, all of which, and more especially the last named, are quite susceptible to the disease. Yet at picking time the loss in the case of the Jonathans was only 4 per cent of the crop, while that of the other two varieties was but 1 per cent. In orchards in which during previous years the disease had caused about equally as severe losses as in this one, the losses during 1915 were at least 50 per cent, even in the case of those which had been sprayed. In many unsprayed orchards the crop was a total loss. In the spring of 1916 the same orchard was again examined for cankers and mummies and, as in the year previous, the first infected fruits and the sources of these infections were removed. The task was quite an easy one in 1916, as the work of the two preceding years had nearly eliminated the disease. Only two applications of Bordeaux mixture were made, one early in July and a second about August 1. Throughout the season the apples remained almost entirely free from rot, and examination of both dropped and picked fruit in the autumn revealed so few specimens of infected apples that the damage was considered negligible and impossible to compute on a percentage basis.

In 1917 the orchard had received two sprayings for the prevention of bitter-rot when visited by the writer on July 23. There was practically no rot except on the one tree from which little effort had been made to remove the cankers in previous years. This tree had been infested with so many cankers that it had been marked for removal, as already mentioned, but had finally been spared. The disease had gained considerable headway on this tree and every fruit appeared to be doomed.

GENERAL SUMMARY.

(1) Apple bitter-rot, caused by the fungus *Glomerella cingulata*, occurs in nearly all sections of the world where apples are grown, but reaches its high point of destructiveness in the more southern apple-growing sections of the United States.

(2) The causal organism survives the winter in certain parts of the host, which serve as sources of the infections occurring on the crop of the following year. It may survive in—

- (*a*) Mummies.
  - Clinton, Hasselbring, Burrill and Blair, Alwood, Von Schrenk and Spaulding, Scott, and the writer showed mummies to be important sources of infection.
  - Apparently the fungus lives over in a mummy for only one year.
  - Both those mummies on the tree and those on the ground are important.
- (*b*) Bitter-rot cankers.
  - The cankers were discovered by Simpson in 1902.
  - Von Schrenk and Spaulding proved them to be caused by the bitter-rot organism.
  - Cankers on young vigorous-growing branches do not survive till the next season. Those on older twigs, especially of very susceptible varieties, may survive for years. Different varieties show different degrees of susceptibility to the cankers. Certain ones, such as the Yellow Newtown and York Imperial, are nearly immune, though their fruit, especially that of the Yellow Newtown, is susceptible to the disease.
- (*c*) Cankers other than those of bitter-rot.
  - Especially in western orchards, in which the disease has been particularly severe, *Glomerella cingulata* may be found in cankers and deadwood due to various causes.
- (*d*) Leaves.
  - As first shown by Shear, the fruits of the causal organism may sometimes be found on leaves of the current year when removed and subjected to moist, hot conditions. The writer, however, has never been able to isolate the fungus from leaves of the previous season.
- (*e*) Other host plants.
  - The fungus is able to infect many plants other than the apple.
- (*f*) Infected fruits of the current year.
  - By conidia produced in these secondary sources of infection the disease is carried to sound fruits. This is the principal means by which the disease is spread after the initial infection.

(3) Spore dissemination is comparatively restricted and is carried on through the agency of rain, dew, insects, and possibly birds. Wind is a negligible factor.

(4) Varieties differ greatly as to susceptibility to the disease. Hot, moist weather favors infection.

(5) The removal of mummies and cankers is a practicable and efficient control measure when supplemented by spraying. This treatment gave control in orchards in which in previous years spraying alone had been uniformly unsuccessful.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 685

Contribution from the Bureau of Crop Estimates
LEON M. ESTABROOK, Chief

Washington, D. C. ▼ June 20, 1918

HONEYBEES AND HONEY PRODUCTION IN THE UNITED STATES.

By S. A. JONES,
Chief, Field Service, Bureau of Crop Estimates.

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THE honeybee is the primary conservationist. Supplementing its extremely important service of promoting the pollination of important food and feed crops, it elaborates from the nectar of the plants thus benefited one of the most delicious, nutritious and readily digestible of all foods. The fact that the most important work of the honey bee is not the production of honey, but the carrying of pollen from flower to flower, thus assisting in the fertilization of plants and assuring their fruitfulness, is not always appreciated. Growers of early cucumbers under glass find it necessary to install hives of bees in their hothouses to insure their crop. A rainy, cold spell during fruit bloom, keeping bees from flying, results in little fruit that season. Many people are not aware that they are thus dependent largely upon these busy and sometimes intrusive insects for the fruitfulness of their orchards and gardens. The work of the bees is important not only to the production of tree fruits, but to full seed or fruit production of a number of forages and grains, berries, and vining plants such as the squash and its relatives, not to mention many ornamental plants and trees. Many other varieties of bees than the honey producing kind and a multitude of other insects assist in the work of transferring pollen from plant to plant, but the honeybee is probably the most important single agent, certainly so in the case of fruit trees.

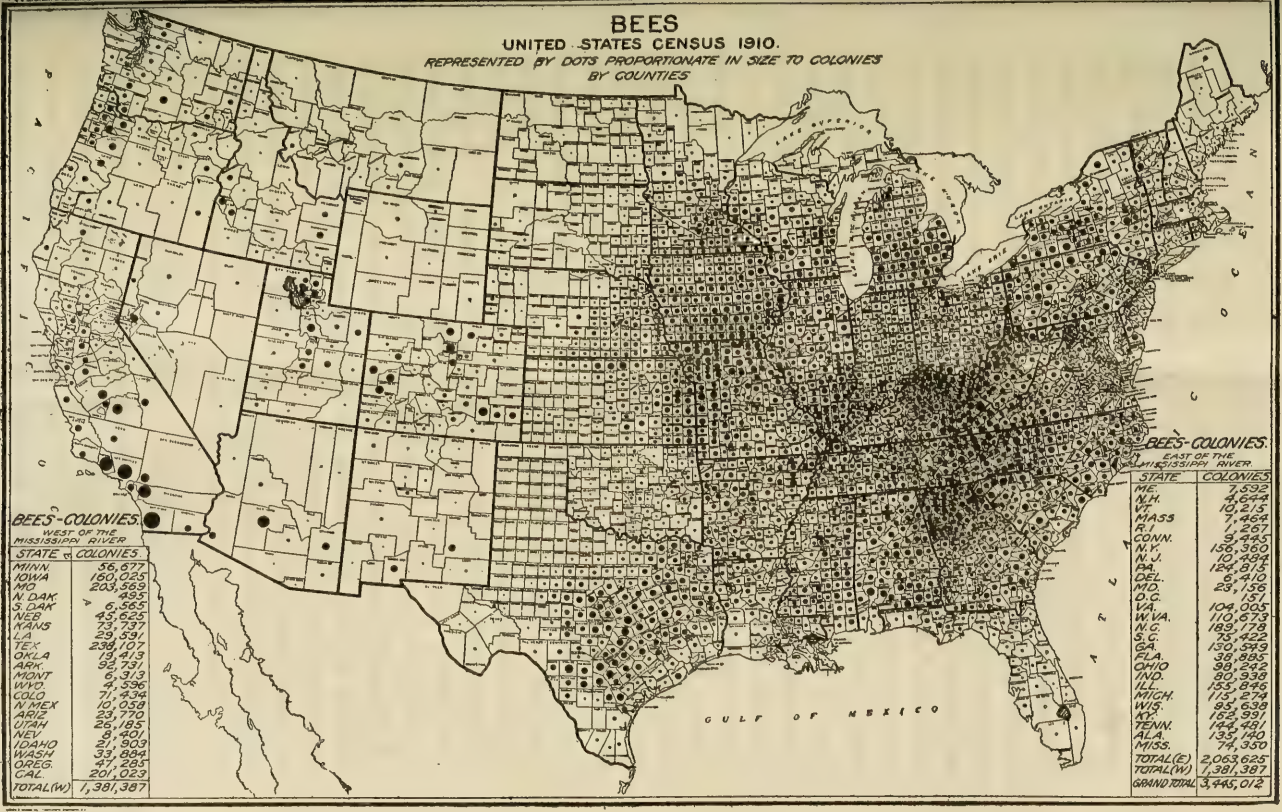
MAP INDICATING DISTRIBUTION OF BEES.

The map printed herewith, showing the distribution of bees in the United States according to the 1910 census, indicates within reasonable limits where bees are most numerous, but some features require a brief explanation. The map shows only bees owned and reported by farmers, omitting the great number of colonies kept in towns or in outapiaries by professional beekeepers, thus making a relatively heavy showing in the more purely rural portions of the country.

The large number of bees indicated in the Southeastern States and particularly in the Appalachian section, while reflecting an undoubted fact, carries an impression stronger than the facts warrant, partially because the territory is predominantly rural, but more because in that region the colonies are, to a greater extent than elsewhere, kept in small boxes, kegs, and similar receptacles which limit the size of the colony and cause heavy swarming. This latter fact tended to further exaggeration because at the time the census was taken swarming was well advanced in the South though hardly begun in the North.

The great importance of beekeeping in the sage and orange sections of southwestern California, the alfalfa and sweet-clover sections of other Western States, the clover belt of the North Central and Northeastern States, in the cotton, horse-mint, and desert plant sections of Texas and in the belt of tupelo and mixed bloom of the coastal plains adjoining the south Atlantic and Gulf coast, are all readily observable.

The great development in certain regions subsequent to the census, as in the Imperial Valley of California (the southeastern section of the State), in southern Idaho (Twin Falls region), and elsewhere, is, of course, not indicated.



BEES

UNITED STATES CENSUS 1910.

REPRESENTED BY DOTS PROPORTIONATE IN SIZE TO COLONIES BY COUNTIES

BEES-COLONIES. WEST OF THE MISSISSIPPI RIVER

STATE	COLONIES.
MINN.	56,677
IOWA	160,025
MO	203,569
N. DAK.	495
S. DAK	6,565
NEB	45,625
KANS	73,737
LA	29,591
TEX	238,107
OKLA	19,413
ARK.	92,731
MONT	6,313
WYO.	4,596
COLO	71,434
N MEX	10,058
ARIZ	23,770
UTAH	26,185
NEV	8,401
IDAHO	21,903
WASH	33,884
OREG.	47,285
CAL.	201,023
TOTAL (W)	1,381,387

BEES-COLONIES. EAST OF THE MISSISSIPPI RIVER.

STATE	COLONIES
ME.	7,592
N.H.	4,644
VT.	10,215
MASS	7,464
R.I	1,267
CONN.	9,445
N.Y.	156,360
N.J.	10,484
PA.	124,815
DEL.	6,410
MD.	23,156
D.C.	151
VA.	104,005
W.VA.	110,673
N.C.	189,178
S.C.	75,422
GA.	130,549
FLA.	38,885
OHIO	98,242
IND.	80,938
ILL.	155,846
MICH.	115,274
WIS.	95,638
KY.	152,991
TENN.	144,481
ALA.	135,140
MISS.	74,350
TOTAL (E)	2,063,625
TOTAL (W)	1,381,387
GRAND TOTAL	3,445,012

MAP SHOWING DENSITY OF BEE CULTURE IN THE UNITED STATES.

EXTENT OF INDUSTRY.

The importance of the honey industry in the United States is realized by few, even of those who have given some attention to the subject, owing to the fact that the census figures, which are naturally looked to for information, report only concerning the bees belonging to farmers, whereas a large and increasing proportion of the honeybees of the country, producing a still larger proportion of the honey crop, belong to beekeepers other than farmers and are located in villages and towns, or, by permission of the farmer or landowner, are kept in out-of-the-way places on farms or hidden in the recesses of the hills, away from frequented roads where they would be readily observed. Surveys of the beekeeping industry in Massachusetts and Indiana indicate that the census included hardly more than half the actual number of colonies of bees in those States and checks on honey production show similar deficiencies in other States.

The census reports indicate for 1910 a total of 3,445,006 colonies, which, if accepted as representing the number on farms, though it is certain that not all such were recorded, may be taken to indicate in the hands of farmers and all others certainly not less than 5,000,000 colonies, more probably 6,000,000, and possibly more. Leading commercial honey authorities estimate the number to be much higher.

The production of honey in 1909, according to the same authority, was approximately 55,000,000 pounds. That this is far below the facts is certain. The average yields indicated by the census reports are about 16 pounds in 1909 and about 15 pounds in 1900, whereas the average yields as reported to the Bureau of Crop Estimates by honey producers are about 40 pounds per colony. Only a little over half the farms reporting bees gave any figures on honey production to the census enumerators. The proportion that actually produced no honey is unknown, but the actual yields per colony on farms must have been considerably higher than those indicated by these imperfect returns to the census enumerators. The honey producers' reports are more nearly representative of the commercial producer, who often, and probably as a rule, is not a farmer, and it may be safely assumed that the average production per colony of bees not belonging to farmers is considerably higher than of those belonging to farmers. If the most probable figure mentioned, 6,000,000 colonies, be accepted as representing all colonies of bees in the United States and the average yield be considered as 25 pounds, which appears conservative, this would account for a total production of 150,000,000 pounds of honey.

An inquiry of leading manufacturers of beekeepers' supplies concerning sales of 1-pound sections, with a conservative allowance for those produced by small firms and individuals, indicates for the season of 1917 a total of about 55,000,000 such sections, and for 1916 and 1915 about 53,000,000 and 45,000,000 sections, respectively. If we accept the common assumption of 1 pound per section, and allow 5 per cent for wastage of empty sections, this would indicate a production of about 52,000,000 pounds of comb honey in 1917. Reports to the Bureau of Crop Estimates from a list of over 5,000 honey producers indicate that the proportion of comb honey in 1-pound sections to all honey obtained from the bees is about 38 per cent. While this figure reflects the facts for the men reporting to the bureau, it is known to be too high if applied to all honey produced, especially in many Southeastern States, where a true return for all beekeepers would show much higher figures for "chunk" honey and lower for comb as well as extracted. A figure for the United States of 33 per cent of comb would be nearer the truth. If this figure be applied to the indicated production of comb honey, it would point to a total production of about 158,000,000 pounds. Commercial honey handlers consider that the proportion of comb honey is much lower, which, if true, would mean a corresponding increase in the indicated total production. The leading commercial authorities in the United States on honeybees and honey production estimate that the total production is considerably in excess of 200,000,000 pounds.

DEPENDABILITY OF TABLES.

In presenting the material appearing in the following tables it should be stated that so much of these data as are drawn from the reports to the Bureau of Crop Estimates by its list of honey producers are of varying degrees of dependability, according to whether the cooperation in the different States has been full or incomplete. For most of the States data are fairly complete, and for the important producing States of California, Texas, Colorado, all of the North Central group except North Dakota and most of the Central Atlantic and North Atlantic groups they are good, particularly for the years 1916 and 1917. From the States of New Hampshire, Rhode Island, Delaware, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Louisiana, Kentucky, North Dakota, Wyoming, New Mexico, Arizona, Utah, Nevada, Washington, and Oregon responses have been relatively few and the figures given are therefore to be accepted with reserve.

TABLE I.—*Honeybees in the United States.*

State.	Number of colonies of bees on farms (United States census).		Spring count of colonies, year stated, in per cent of previous year. (Report May 1.)					
	June 1, 1900.	Apr. 15, 1910.	1914 compared with the usual number in previous years.	1914 compared with 1913.	1915 compared with 1914.	1916 compared with 1915.	1917 compared with 1916.	1918 compared with 1917.
	Number.	*Number.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Maine	10,857	7,592	98	99	100	107	106	85
New Hampshire	5,520	4,644	94	96	103	100	115	85
Vermont	12,836	10,215	98	98	96	115	105	75
Massachusetts	8,381	7,464	95	96	101	115	106	70
Rhode Island	1,681	1,267	99	99	100	105	105	95
Connecticut	11,438	9,445	85	92	110	85	112	75
New York	187,208	156,360	102	103	90	109	110	80
New Jersey	14,118	10,484	100	103	98	90	106	73
Pennsylvania	161,670	124,815	95	98	96	100	110	65
Delaware	10,187	6,410	100	101	98	103	95	85
Maryland	28,013	23,156	96	100	102	97	108	70
District of Columbia	59	151	....	....	....	....	....	....
Virginia	139,064	104,005	98	100	106	100	100	77
West Virginia	111,417	110,673	99	101	95	102	100	75
North Carolina	244,539	189,178	101	103	102	94	96	88
South Carolina	93,958	75,422	100	100	101	100	100	115
Georgia	187,919	130,549	95	98	100	98	110	110
Florida	39,753	38,895	101	103	100	100	96	115
Ohio	151,391	98,242	105	108	98	98	108	65
Indiana	117,148	80,938	110	115	90	102	112	70
Illinois	179,953	155,846	97	100	92	105	118	80

TABLE I.—*Honeybees in the United States*—Continued.

State.	Number of colonies of bees on farms (United States census).		Spring count of colonies, year stated, in per cent of previous year. (Report May 1.)					
	June 1, 1900.	Apr. 15, 1910.	1914 compared with the usual number in previous years.	1914 compared with 1913.	1915 compared with 1914.	1916 compared with 1915.	1917 compared with 1916.	1918 compared with 1917.
	Number.	*Number.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Michigan	100,397	115,274	101	103	104	98	106	80
Wisconsin	106,090	95,638	100	105	103	101	103	96
Minnesota	45,877	56,677	100	105	102	115	96	108
Iowa	138,811	160,025	105	115	94	117	105	85
Missouri	205,110	203,569	90	93	86	115	112	83
North Dakota	279	495	110	105	105	120	125	120
South Dakota	2,063	6,565	105	115	105	120	95	95
Nebraska	52,143	45,625	95	97	92	150	112	93
Kansas	88,594	73,737	85	90	100	108	108	96
Kentucky	203,820	152,991	115	110	102	105	107	70
Tennessee	225,788	144,481	100	115	102	80	108	88
Alabama	205,369	135,140	105	105	101	105	106	115
Mississippi	95,257	74,350	94	95	100	103	92	96
Louisiana	35,231	29,591	93	96	96	105	106	115
Texas	392,644	238,107	115	112	115	94	95	74
Oklahoma	[1] 20,137	19,413	107	110	99	103	109	100
Arkansas	111,138	92,731	99	100	92	102	88	105
Montana	1,801	6,313	120	110	125	112	88	125
Wyoming	1,020	4,596	106	110	120	112	112	125
Colorado	59,756	71,434	115	120	101	103	100	107
New Mexico	6,164	10,052	110	115	115	108	103	98
Arizona	18,991	23,770	115	110	110	108	96	100
Utah	33,818	26,185	110	105	105	98	80	112
Nevada	5,692	8,401	110	105	100	105	75	112
Idaho	19,240	21,903	150	130	105	115	60	135
Washington	30,870	33,884	108	105	103	100	110	115
Oregon	55,585	47,285	110	108	98	95	95	105
California	129,444	201,023	85	93	110	104	92	95
United States	4,108,239	3,445,006	100.4	104.2	101.4	102.9	101.5	88.7

[1] Includes Indian Territory.

COLONIES OF BEES IN THE UNITED STATES.

The first census to make inquiry concerning the number of colonies of bees on farms in the United States was the twelfth, which reports the number of colonies belonging to farmers on June 1, 1900, to be 4,108,239. The next census (1910) reported 3,445,006 on hand as of April 15, 1910, but the last showing is unfairly low even compared with the first, because the date of the last census is 45 days earlier than the former and at a period of the year when the number of colonies is increasing rapidly from swarming. Making allowance for this difference, the number in 1910 should perhaps have been about 3,700,000 colonies. It seems unquestionable that the number of colonies of bees in the hands of farmers did actually decline in the intervening 10 years, which had not been as a rule favorable for honey production and had also been marked by considerable losses of bees from diseases of the brood, which often destroyed whole apiaries, containing sometimes hundreds of colonies. The period of the Nineties preceding the census of 1900 had, to the contrary, been favorable for bees, aside from disease in some sections. However, the report of the 1910 census represents more nearly than the former one the customary basis of number of colonies as recognized by bee keepers, namely, the spring count, i. e., the number of working colonies of bees remaining on hand (excluding new swarms of the current year), at about the settled beginning of the spring nectar flow, which, for the country at large, would average about May 1.

The changes in numbers of bees since 1910 may be followed in a general way by a study of the percentages of increase shown in connection with the census figures just quoted in Table I. The bureau's first inquiry, made on May 1, 1914, asked concerning the number of colonies compared with the usual. The usual, being the average of the preceding few years, would represent figures in all probability very close to those of the census year 1910. The responses indicated an increase over the usual of 0.4 per cent and an increase over 1913 of over 4 per cent, which would point to a small decline subsequent to 1910, before the beginning in 1914 of the upward trend which has been observed in each succeeding year. The total increase since 1910 to the spring of 1917 appears to be not far from 10 per cent. This growth has been largely within the ranks of the professional honey producers, those making this a principal business, rather than among the farmer beekeepers, not fully represented in this estimate, who, for reasons mentioned later, quite possibly have less rather than more bees, certainly so in many sections where bee diseases have invaded new territory.

TABLE II.—*Honeybees: Per cent of total swarming, by months.*

State.	Proportion of total annual increase of colonies in—					
	March.	April.	May.	June.	July.	August.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Maine	....	....	7.3	50.1	38.7	3.9
New Hampshire	....	....	9.7	48.5	28.3	13.5
Vermont	....	....	5.8	59.2	31.3	3.7
Massachusetts	....	1.4	20.8	47.1	21.2	9.5
Rhode Island	....	....	5.0	80.0	15.0	....
Connecticut	....	.5	25.4	49.7	21.7	2.7
New York	....	....	9.5	54.4	28.5	7.6
New Jersey	....	1.0	29.4	48.5	11.8	9.3
Pennsylvania	....	.7	19.7	58.3	15.8	5.5
Delaware	....	....	37.0	50.0	8.0	5.0
Maryland	....	1.7	45.4	42.0	9.3	1.6
Virginia	0.3	3.9	45.7	39.3	10.5	.3
West Virginia	....	1.0	26.2	45.5	25.6	1.7
North Carolina	.2	12.2	49.6	30.6	6.9	.5
South Carolina	5.1	56.6	35.9	2.4	....	....
Georgia	15.7	50.1	24.8	4.4	2.6	2.4
Florida	33.2	38.8	15.3	8.8	1.8	2.1
Ohio	....	.7	21.3	55.1	20.6	2.3
Indiana	....	2.5	20.4	59.0	15.2	2.9
Illinois	....	.2	18.0	58.5	19.0	4.3
Michigan	....	....	3.9	56.9	34.3	4.9
Wisconsin	....	....	5.5	58.4	30.7	5.4
Minnesota	....	....	4.5	55.0	33.8	6.7
Iowa	....	.5	10.7	59.1	25.4	4.3
Missouri	....	3.6	26.7	47.6	16.6	5.5
North Dakota	....	....	5.0	51.6	36.7	6.7
South Dakota	....	....	7.8	44.1	35.1	13.0
Nebraska	....	....	13.7	51.2	27.7	7.4
Kansas	....	.9	27.3	46.9	17.4	7.5
Kentucky	....	.7	33.4	51.9	11.4	2.6

TABLE II.—*Honeybees: Per cent of total swarming, by months*—Contd.

State.	Proportion of total annual increase of colonies in—					
	March.	April.	May.	June.	July.	August.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Tennessee		9.6	51.7	30.7	6.1	1.9
Alabama	4.7	37.0	32.5	19.0	1.8	5.0
Mississippi	1.8	45.4	30.4	15.0	6.5	.9
Louisiana	5.8	42.5	28.8	13.2	7.1	2.6
Texas	11.1	38.1	28.3	14.4	4.6	3.5
Oklahoma		4.1	47.7	35.2	10.2	2.8
Arkansas	.8	23.5	40.4	25.0	3.8	6.5
Montana			9.6	38.4	42.3	9.7
Wyoming			2.5	22.0	53.0	22.5
Colorado		.7	11.8	34.9	37.8	14.8
New Mexico		3.7	34.0	31.1	15.4	15.8
Arizona	18.0	30.0	31.0	12.0	4.0	5.0
Utah			16.1	49.4	27.8	6.7
Nevada		13.5	50.0	33.0	5.0	1.5
Idaho			9.8	50.0	35.7	4.5
Washington		2.5	27.0	42.1	21.5	6.9
Oregon		5.2	28.5	52.1	10.6	3.6
California	5.9	41.7	31.2	12.1	6.4	2.7
United States	3.5	16.4	25.1	36.2	14.8	4.0

INCREASE BY SWARMING.

The net changes in number of colonies from year to year is the balance between the increase by swarming, natural and artificial, and the losses. The annual primary increase by swarming must, to offset the losses, average between 15 and 20 per cent of the number of colonies, not counting the swarms that escape and establish themselves in hollow trees, rock cavities, etc. The number so escaping must be quite large, but can not be determined. Most of the increase is by natural swarming, but as this often reduces the production of surplus honey, there is an increasing tendency among beekeepers, amounting to a practice among a large part of those who make this a regular business, to prevent natural swarming during the main nectar flow, in order that the bees may devote all of their energies to the gathering of honey. Provision for increase in number of colonies, if desired, is made later by the method of artificial swarming, which is, simply, division by the apiarist, after the removal of the honey surplus, of one strong colony into two or more, which are then allowed or assisted to build up in number and store supplies, so that by winter they may be strong colonies.

The results of an inquiry concerning the per cent of the total swarming, natural or artificial, occurring each month is shown in Table II.

In Florida, Arizona, California, and Texas, and occasionally in other States along the southern edge of the country, a few swarms will sometimes issue in February. It may be seen that swarming begins quite generally along the Gulf coast and in Arizona and Texas in March, becomes heavy in these States in April, continues there with lessened intensity during May, in which month it begins strongly throughout the central tiers of States and slightly in the northern tiers. In June it largely terminates in all the southern group, but reaches its maximum in the Central and Northern States. During July swarming continues heavy in the far Northern States and in the elevated portions of the Southerly and Western States, while in August swarming is limited, except in a few localities. Swarming occurs in September in certain sections where there is a heavy flow of nectar that month, such as the swamp sections of northern Indiana, although for the country as a whole and for all States swarming is practically over by the beginning of that month.

WINTERING BEES.

The provision made in the way of food supplies and extra protection for wintering, bears directly upon the rate of loss. Inquiry was made concerning winter food requirements of bees and the winter protection given, and the results are shown in Table III. Since the heaviest, and quite possibly the majority, of losses are due to starvation, inquiry has been made regularly in November concerning the supply of honey in the hive for winter, and the results are shown in this table. These last figures can not, unfortunately, be taken to reflect the average for all colonies. but more nearly that for colonies in the possession of progressive and professional beekeepers. These figures show that while con-

TABLE III.—*Honeybees: Winter confinement, food supply, and protection.*

State.	Usual length of time between fall and spring nectar flows.	Longest period confined to hives in usual winter without a flight.	Honey needed to winter a colony outdoors.	Honey on hand per colony at beginning of winter.				Extra winter protection furnished colonies.						
				1914–15	1915–16	1916–17	1917–18	Cellar.	Double-walled and packed hives.	Packed or in cellar (not separated).	Packed super.	Wrappings of tar paper, etc.	Straw covering and miscellaneous.	Total per cent given winter protection.
	Months.	*Months.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Maine					31	35	30							
New Hampshire					31	35	37							
Vermont	7.6	3.6	29	25	30	32	26	67	14				14	95
Massachusetts	6.2	1.9	29	34	34	32	30	17	39	20				76
Rhode Island					29	35	31							
Connecticut	6.1	1.7	35	28	25	31	28	6		46				50
New York	7.2	2.8	31	29	34	34	32	25	33	22				80
New Jersey	5.7	2.0	25	27	29	33	35		30					30
Pennsylvania	7.0	2.2	31	30	34	34	34	1	35	4	15	3	2	60
Delaware					21	30	34							
Maryland	6.0	1.3	30	30	35	31	32	1	9		10	5		25
Virginia	5.7	1.3	28	32	27	32	30				3		1	4
West Virginia	7.0		35	35	34	35	30		10					10
North Carolina	4.6	1.2	26	25	27	27	28		5					5
South Carolina	5.2	1.0	30	31	30	40	31		2					2
Georgia	4.8	1.0	27	29	30	33	29						1	1
Florida	4.2	.5	40	40	31	28	32							0
Ohio	6.3	2.0	29	33	33	35	31	10	26		3	6		45
Indiana	6.4	2.0	31	34	34	35	31	3	30		4	3		40
Illinois	6.8	2.5	32	30	36	42	37	20	26		2		2	50

Michigan	7.0	3.2	29	29	35	35	30	30	13	34			3	80
Wisconsin	7.0	3.4	31	34	32	33	32	74	16	5		2		97
Minnesota	7.6	3.3	36	38	38	33	34	69		30				99
Iowa	6.5	2.2	32	28	41	39	37	40	10	21		2	2	75
Missouri	6.4	1.6	33	26	37	39	39		5		12		3	20
North Dakota						35	36							
South Dakota	7.0	2.7	37	41	38	37	40	44	1	6			19	70
Nebraska	6.4	1.3	32	35	35	42	37	1	30		12		7	50
Kansas	5.7	1.6	33	36	35	35	35		1		3	1	5	10
Kentucky	5.9	1.4	34	42	33	35	34		2		6			8
Tennessee	5.5	1.1	32	36	27	29	27		2			2		4
Alabama	5.0	.6	35	36	30	34	41				1			1
Mississippi	5.6	.5	29	32	30	27	34							0
Louisiana		.5	30	32	30	38	35							0
Texas	4.1	.6	34	41	32	36	28				1			1
Oklahoma	5.9	1.2	30	25	31	35	36					8		8
Arkansas	4.0	.9	35		26	25	31							0
Montana					27	37	42							
Wyoming	8.5	1.4	25	38	37	60	48	26	9			30		65
Colorado	7.7	1.2	37	39	36	36	40	1	1		5	4	1	12
New Mexico	6.3	.5	36	36	34	39	30		2		2			4
Arizona	3.6	.1	33	34	36	28	33							[1] 0
Utah	8.8	1.4	49	44	34	42	41	1	30		12	7		50
Nevada	7.0	1.0	40	35	20	40	44							[1] 0
Idaho	7.3	3.1	37	39	43	35	38	3	4	20	2	1	25	55
Washington	6.4	1.2	37	41	36	34	32		3		1	1		5
Oregon	5.0	.7	26	31	35	32	31		7					7
California	4.5	.5	33	44	39	34	34							
U. S. Average	5.8	1.5	31.9	33.5	32.5	34.5	32.9	9.1	9.0	4.3	2.5	.9	1.0	26.8

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[1] No protection in the main honey producing sections of California.

finement is less as one proceeds southward, and limited to a few days at a time in the far Southern States, the winter consumption of stores increases rather than diminishes going southward, probably owing to greater winter activity of the bees. Little winter protection is provided for bees where not absolutely needed. Practically none is given in the Southern States, and but little in the middle tier, but in the far Northern States it is the general rule to pack or cellar the bees. Favorable methods of packing and the extent to which used in the different States are indicated in the table.

TABLE IV.—*Honeybees: Losses by disease and in wintering.*

State.	Summer losses of colonies from disease.			Winter losses of colonies from all causes.			
	1915	1916	1917	1914–15	1915–16	1916–17	1917–18
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Maine	5.0	1.2	1	....	9.5	5.8	21
New Hampshire	0	2.0	1.3	....	12.0	17.5	25
Vermont	2.0	2.0	.3	11.0	9.0	15.2	18
Massachusetts	1.0	4.0	2	13.7	23.0	12.1	41
Rhode Island	1.0	0.3	0	....	19.0	2.3	20
Connecticut	0.2	10.0	4.7	16.0	22.0	5.9	31
New York	0.9	3.0	1.8	19.8	15.0	8.2	23
New Jersey	5.0	3.5	1.6	6.1	25.8	10.6	30
Pennsylvania	4.0	3.0	2.1	15.7	17.1	11.8	40
Delaware	0	1.5	5	....	14.0	17.3	20
Maryland	0.8	0.5	2.1	11.4	19.0	6.3	41
Virginia	2.3	1.0	3.7	11.2	19.2	10.7	38
West Virginia	....	3.0	1.1	5.7	14.7	8.8	31
North Carolina	0	0	2.2	5.1	17.0	15.5	17
South Carolina	0.4	0	2.5	13.1	11.2	13.5	11
Georgia	1.0	0	1.5	14.7	10.1	4.5	4
Florida	0	4.5	2.2	8.4	11.7	5.0	4
Ohio	2.0	3.5	2	16.1	16.6	10.7	34
Indiana	1.5	2.0	4.1	10.8	17.4	9.7	27
Illinois	2.0	1.3	5.6	11.3	10.7	6.7	21
Michigan	2.0	3.8	2.7	10.7	16.0	10.2	22
Wisconsin	1.5	6.0	2.5	5.4	14.4	10.0	13
Minnesota	0.1	1.5	2.2	16.5	10.0	12.6	14
Iowa	2.0	4.0	2.7	13.0	10.8	10.6	18
Missouri	2.4	1.0	1	31.0	12.6	7.9	17
North Dakota	....	0	0	....	8.0	5.3	5
South Dakota	5.0	2.0	2.5	7.8	15.7	13.5	14
Nebraska	5.0	2.0	2.7	15.8	16.1	12.5	21
Kansas	0.1	1.0	2.6	7.4	11.9	8.1	12
Kentucky	1.0	4.0	1.9	9.5	10.9	14.0	35

TABLE IV.—*Honeybees: Losses by disease and in wintering*—Continued.

State.	Summer losses of colonies from disease.			Winter losses of colonies from all causes.			
	1915	1916	1917	1914–15	1915–16	1916–17	1917–18
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Tennessee	0	1.0	1.6	8.9	20.9	5.9	24
Alabama	0	0	.3	17.3	11.7	7.6	6
Mississippi	1.0	0	5.3	23.2	7.9	7.1	7
Louisiana	0	0	.3	7.7	10.4	14.5	4
Texas	0.5	1.0	8	7.1	8.0	6.0	24
Oklahoma	0.3	0.5	5	15.4	11.4	7.5	13
Arkansas	0	0.5	1.6	25.0	15.7	13.2	9
Montana	3.0	0.3	1.2	....	24.1	22.7	14
Wyoming	0.3	0.3	4	19.1	5.7	20.0	8
Colorado	2.0	2.0	4	10.5	11.2	14.3	8
New Mexico	1.4	1.0	2.6	9.2	4.8	9.0	8
Arizona	1.0	3.0	1.1	2.0	7.1	3.9	6
Utah	4.0	3.0	1.4	10.5	11.0	30.4	6
Nevada	....	2.0	.5	5.0	1.9	14.7	7
Idaho	5.0	1.5	1.2	5.9	10.5	46.6	5
Washington	2.0	3.0	3.2	19.8	17.8	9.0	6
Oregon	0	3.0	7.4	3.9	20.4	20.0	8
California	4.5	5.0	6.4	5.0	8.5	10.0	11
United States	1.5	2.3	3.5	12.6	13.3	10.1	18.7

LOSSES.

The losses of bees by disease, principally foulbrood, during the summer, range from practically nothing to almost 10 per cent in some States, though the latter figures are exceptional and may be due to mistaking starvation for disease. The losses to bees in wintering are severe, ranging for the United States as a whole from 10 to almost 15 per cent, and rising in some States to almost 50 per cent in the winter of 1916–17. Details for three years are shown in Table IV. The losses for the winter of 1917–18, owing to an early and exceedingly severe winter, are reported at 18.7 per cent, more than a half greater than the average of the three preceeding winters, and the heaviest in a long period of years.

TABLE V.—*Honeybees: Winter losses, causes and percentages of.*

State.	Causes and percentages of winter losses.											
	Queen lost or failing.			Starvation.			Cold, exposure, smothering.			Moths and ants.		
	1914–15	1915–16	1916–17	1914–15	1915–16	1916–17	1914–15	1915–16	1916–17	1914–15	1915–16	1916–17
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Maine	.....	0.3	0.6	.....	5.0	1.6	.....	3.2	1.3	.....	.....	0.3
New Hampshire	.....	.....	.....	.....	9.4	4.6	.....	2.0	.9	.....	.....	.....
Vermont	0.1	.5	.9	0.4	4.7	4.8	0.1	2.6	5.0	.....	.....	.....
Massachusetts	.....	.2	.5	.....	15.4	4.0	2.1	5.0	2.3	.....	.....	.....
Rhode Island	.....	.....	.....	.....	5.7	.....	.....	3.0	2.3	.....	.....	.....
Connecticut	.....	1.8	.4	16.0	7.0	1.3	.....	10.0	1.2	.....	.....	.4
New York	1.2	2.0	2.1	.6	10.1	2.1	.1	2.0	.5	.....	.....	.....
New Jersey	2.2	5.0	2.1	.....	11.9	2.8	.....	3.5	4.3	.....	.....	.....
Pennsylvania	2.2	.5	1.6	1.2	7.5	3.3	1.7	3.0	1.3	.....	0.3	.....
Delaware	.....	5.0	2.4	.....	6.0	7.7	.....	.....	1.3	.....	2.0	2.3
Maryland	.3	3.0	.9	4.7	11.2	1.8	.....	.6	.7	.2	1.5	.6
Virginia	1.5	.8	1.0	1.8	13.3	3.0	.1	1.8	.1	.6	1.5	.4
West Virginia	.....	1.5	.8	.....	8.3	2.7	.....	1.4	3.3	.....	.5	.5
North Carolina	.4	.4	.9	2.6	11.4	6.7	.....	2.0	2.7	1.7	2.0	1.1
South Carolina	5.7	1.5	.7	3.3	5.5	9.9	.....	1.5	.....	3.7	.5	2.3
Georgia	2.8	1.5	3.0	10.7	3.1	.....	.....	.5	.4	1.1	4.0	.8
Florida	2.3	2.0	1.2	.....	2.0	2.1	.....	.2	.....	.....	4.0	.3
Ohio	.8	2.2	2.1	.....	6.7	.9	2.6	2.0	4.8	.....	.2	.....
Indiana	.9	2.0	2.4	1.4	10.2	.9	2.2	1.0	3.8	.....	.2	.....
Illinois	2.1	1.2	1.8	.5	4.5	1.3	2.5	1.6	1.0	.....	1.4	.....
Michigan	2.9	2.0	1.4	2.6	10.0	2.8	1.6	1.5	1.1	.....	.2	.....
Wisconsin	4.1	3.0	1.8	.....	6.6	3.4	.1	1.2	1.8	.....	.....	.1
Minnesota	.2	2.2	1.5	10.5	2.6	4.5	.....	2.6	.8	.....	.3	.2
Iowa	2.4	2.5	2.1	.1	4.5	1.7	.....	1.5	4.2	.....	.3	.3
Missouri	.....	3.0	1.5	.....	2.2	1.6	4.3	1.7	2.3	.....	2.0	.8
North Dakota	.....	.....	.....	.....	4.0	1.8	.....	.....	1.8	.....	.....	.....
South Dakota	.4	.7	.8	2.8	5.0	5.4	3.0	3.0	.8	.....	.....	.....
Nebraska	2.4	3.0	2.4	3.6	3.8	1.5	2.6	3.5	5.9	.....	.2	.....
Kansas	.4	1.0	3.9	3.5	6.3	3.0	.1	1.1	.3	.....	.8	.....
Kentucky	.9	2.4	.8	2.7	6.0	1.0	.7	1.0	8.1	.1	.1	.....
Tennessee	1.4	.6	.8	3.7	12.6	3.8	.3	1.5	.5	.3	1.2	.3
Alabama	.8	1.0	.9	10.5	5.0	5.3	.....	.2	.....	.1	3.0	.5
Mississippi	.7	.4	.7	11.4	2.4	4.3	.....	.....	.4	1.3	3.0	.....
Louisiana	2.1	.2	1.5	5.6	1.8	3.8	.....	.....	.....	.....	5.6	2.0
Texas	1.5	1.5	2.8	3.1	3.2	2.4	.....	.1	.1	.2	1.5	.2

TABLE V.—*Honeybees: Winter losses, causes and percentages of*—Continued.

State.	Causes and percentages of winter losses.											
	Queen lost or failing.			Starvation.			Cold, exposure, smothering.			Moths and ants.		
	1914–15	1915–16	1916–17	1914–15	1915–16	1916–17	1914–15	1915–16	1916–17	1914–15	1915–16	1916–17
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Oklahoma	1.0	0.2	1.0	1.0	5.6	3.6	2.4	2.0	0.7	......	3.0	0.7
Arkansas	......	3.5	1.1	25.0	8.0	8.8	......	.1	1.9	......	3.0	.9
Montana	......	.5	1.9	......	.5	1.3	......	22.1	15.8	......	......	......
Wyoming	1.7	2.0	.5	17.4	1.0	.4	......	1.0	13.0	......	......	......
Colorado	2.3	2.0	2.0	.5	2.0	.7	1.4	2.5	8.7	......	......	......
New Mexico	1.7	2.2	1.6	......	.2	2.2	......	.6	1.9	......	1.1	.1
Arizona	1.5	.5	.9	......	5.0	2.3	......	......	......	......	......	......
Utah	4.8	2.5	.7	......	1.3	.8	1.0	4.9	19.9	......	......	......
Nevada	......	......	......	......	......	......	......	......	14.7	......	......	......
Idaho	2.6	2.1	.9	.2	4.0	.4	.2	1.0	24.6	......	......	......
Washington	.9	1.5	.8	.2	4.0	3.5	16.9	8.4	1.3	......	.3	.1
Oregon	2.2	1.2	.6	......	2.0	1.2	......	13.0	11.7	.2	1.0	......
California	2.5	3.0	2.5	.1	1.0	2.4	......	.8	1.2	......	.2	......
U. S. average	1.5	1.8	1.7	3.2	6.0	2.7	.9	1.7	2.4	.3	1.1	.3

State.	Causes and percentages of winter losses.								
	Foul brood and other diseases.			Poor honey, dysentery.			Late and weak swarms.		
	1914–15	1915–16	1916–17	1914–15	1915–16	1916–17	1914–15	1915–16	1916–17
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Maine	......	......	......	......	0.5	......	......	0.2	......
New Hampshire	......	......	......	......	.4	12.0	......	.2	......
Vermont	......	......	0.3	2.7	......	2.1	0.1	.8	......
Massachusetts	......	0.8	.3	.5	......	.2	11.1	.3	1.3
Rhode Island	......	......	......	......	......	......	......	......	......
Connecticut	......	3.0	.1	......	......	......	......	......	1.7
New York	......	......	.1	9.4	.3	.2	6.4	......	1.1
New Jersey	0.1	2.0	.6	.5	......	.1	1.5	......	......
Pennsylvania	......	3.0	3.2	1.8	.4	1.3	2.7	.6	......
Delaware	......	......	......	......	......	......	......	......	1.3
Maryland	......	......	.9	3.7	.2	.1	1.4	......	1.0
Virginia	......	.1	1.7	1.3	1.0	1.6	1.4	.3	1.9
West Virginia	......	......	......	5.7	1.5	.2	......	1.0	.7
North Carolina	......	.5	......	......	......	1.1	.4	.5	.8
South Carolina	......	2.0	......	......	......	.7	.4	.2	......

TABLE V.—*Honeybees: Winter losses, causes and percentages of*—Continued.

State.	Causes and percentages of winter losses.								
	Foul brood and other diseases.			Poor honey, dysentery.			Late and weak swarms.		
	1914–15	1915–16	1916–17	1914–15	1915–16	1916–17	1914–15	1915–16	1916–17
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Georgia	......	......	0.1	......	......	......	......	0.3	......
Florida	......	3.0	......	......	......	0.5	2.3	......	......
Ohio	1.5	1.2	.3	5.4	1.0	.4	.2	1.0	0.2
Indiana	.6	.3	.1	2.9	.3	.3	......	.2	.2
Illinois	......	.4	.2	4.3	......	.2	1.8	.1	.9
Michigan	.7	.3	1.2	2.1	1.8	.8	.2	.2	.3
Wisconsin	......	.1	.3	.6	2.0	.5	......	.3	.6
Minnesota	......	......	......	5.3	.5	2.2	......	.1	1.5
Iowa	1.3	.2	.1	3.4	.5	.4	2.7	......	.7
Missouri	......	.7	.5	3.3	......	......	......	2.0	.2
North Dakota	......	......	......	......	......	......	......	4.0	......
South Dakota	......	3.5	.2	......	......	4.0	......	.5	.9
Nebraska	......	1.0	.5	3.6	......	......	......	2.0	......
Kansas	......	......	......	......	.2	......	3.3	1.0	.1
Kentucky	.2	.5	1.1	3.2	......	.9	......	.2	.5
Tennessee	......	.3	......	1.0	2.5	......	1.7	......	.4
Alabama	.1	2.0	.7	......	.1	......	......	.1	.1
Mississippi	2.2	.7	1.5	.5	......	......	......	......	.2
Louisiana	......	......	......	......	......	......	......	......	......
Texas	.2	.1	......	......	......	......	1.5	......	.4
Oklahoma	......	......	......	3.	......	.1	2.0	.3	......
Arkansas	......	.1	......	......	......	......	......	......	......
Montana	......	.8	1.5	......	......	1.3	......	.2	.8
Wyoming	......	......	.2	......	......	.6	......	1.0	.4
Colorado	.6	3.5	.4	.8	.1	1.7	1.5	.5	.4
New Mexico	......	......	......	......	......	......	......	......	1.4
Arizona	.2	......	......	......	......	......	.3	......	.1
Utah	.1	1.5	.2	3.3	......	1.5	......	2.0	6.8
Nevada	......	......	......	......	......	......	......	......	......
Idaho	......	.5	......	.6	2.0	[1]19.8	.6	.2	.6
Washington	......	.2	.5	......	1.5	......	.8	......	.7
Oregon	1.0	.6	1.6	......	2.0	5.5	......	.5	......
California	1.2	2.0	3.4	......	......	......	.3	.5	......
U. S. average	.3	.7	.8	2.1	.5	.6	1.1	.4	.5

[1] Honey dew, coupled with extremely severe winter.

TABLE V.—*Honeybees: Winter losses, causes and percentages of*—Continued.

State.	Causes and percentages of winter losses.								
	Lack of young bees.			Miscellaneous and unknown.			Total loss of colonies.		
	1914–15	1915–16	1916–17	1914–15	1915–16	1916–17	1914–15	1915–16	1916–17
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Maine	......	0.3	......	......	0.2	2.1	......	9.5	5.8
New Hampshire	......	......	......	......	......	......	......	12.0	17.5
Vermont	......	......	......	7.6	1.0	2.1	11.0	9.0	15.2
Massachusetts	......	.8	0.7	......	......	2.8	13.7	23.0	12.1
Rhode Island	......	......	......	......	1.0	......	......	19.0	2.3
Connecticut	......	......	......	......	.2	.7	16.0	22.0	5.9
New York	......	.1	.1	2.1	.5	1.9	19.8	15.0	8.2
New Jersey	1.3	1.4	......	.5	2.0	.7	6.1	25.0	10.6
Pennsylvania	.2	.1	.4	5.9	1.7	.7	15.7	17.0	11.8
Delaware	......	......	......	......	1.0	2.3	......	14.0	17.3
Maryland	1.1	......	......	......	2.5	.3	11.4	19.0	6.3
Virginia	.4	.3	......	4.1	1.0	.9	11.2	19.2	10.7
West Virginia	......	......	......	......	.5	.7	5.7	14.7	8.8
North Carolina	......	......	......	......	.2	2.2	5.1	17.0	15.5
South Carolina	......	......	......	......	......	......	13.1	11.2	13.5
Georgia	......	......	......	.1	.7	.2	14.7	10.1	4.7
Florida	......	......	......	3.8	.5	1.0	8.4	11.7	5.0
Ohio	5.5	.3	.6	.1	2.0	1.3	16.1	16.6	10.7
Indiana	1.7	.7	.4	1.1	2.5	1.5	10.8	17.4	9.7
Illinois	......	......	......	.1	1.5	1.2	11.3	10.7	6.7
Michigan	......	......	.3	.6	......	2.4	10.7	16.0	10.2
Wisconsin	......	.5	......	.6	.7	1.5	5.4	14.4	10.0
Minnesota	......	.6	.2	.5	1.2	1.7	16.5	10.0	12.6
Iowa	2.0	.5	.4	1.1	.8	.8	13.0	10.8	10.6
Missouri	......	......	.5	23.4	1.0	.4	31.0	12.6	7.9
North Dakota	......	......	......	......	......	1.8	......	8.0	5.3
South Dakota	.8	......	......	.8	3.0	1.5	7.8	15.7	13.5
Nebraska	......	.1	.6	3.6	2.5	1.6	15.8	16.1	12.5
Kansas	......	......	.1	.1	1.5	.7	7.4	11.9	8.1
Kentucky	......	......	.1	1.7	.7	1.6	9.5	10.9	14.0
Tennessee	......	.2	......	.5	2.0	.2	8.9	20.9	5.9
Alabama	......	......	......	5.8	.4	......	17.3	11.7	7.6
Mississippi	......	......	......	7.1	1.4	......	23.2	7.9	7.1
Louisiana	......	......	......	......	1.0	8.0	7.7	10.4	14.5
Texas	......	1.5	......	.6	.1	.1	7.1	8.0	6.0
Oklahoma	......	......	......	8.7	.3	1.4	15.4	11.4	7.5
Arkansas	......	......	......	......	1.0	.5	25.0	15.7	13.2
Montana	......	......	......	......	......	......	......	24.1	22.7
Wyoming	......	......	......	......	.7	4.9	19.1	5.7	20.0
Colorado	1.1	.1	.3	2.3	.5	......	10.5	11.2	14.3

TABLE V.—*Honeybees: Winter losses, causes and percentages of*—Continued.

State.	Causes and percentages of winter losses.								
	Lack of young bees.			Miscellaneous and unknown.			Total loss of colonies.		
	1914–15	1915–16	1916–17	1914–15	1915–16	1916–17	1914–15	1915–16	1916–17
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
New Mexico	2.5	......	1.5	5.0	0.7	0.2	9.2	4.8	9.0
Arizona	......	......	......	......	1.6	.6	2.0	7.1	3.9
Utah	1.0	......	......	.3	.3	.5	10.5	11.0	30.4
Nevada	......	......	......	5.0	1.9	......	5.0	1.9	14.7
Idaho	1.1	0.2	......	.6	.5	.3	5.9	10.5	46.6
Washington	......	.4	1.6	1.0	1.5	.5	19.8	17.8	9.0
Oregon	......	......	......	.5	.1	......	3.9	20.4	20.0
California	......	......	......	.9	1.0	.4	5.0	8.5	10.0
U. S. average	.4	.2	.2	2.8	.9	.9	12.6	13.3	10.1

CAUSES OF WINTER LOSS.

The principal causes of winter loss, as reported, are shown by States in Table V, being in order starvation, cold, queenlessness, weakened condition resulting from disease or poor honey, such as late unripened aster for the winter food supply, a small cluster of bees due to late swarming or other causes, and lack of young bees from any cause but due usually to a failing queen or an unfavorable autumn for brood rearing.

Starvation, the most frequently reported cause of loss, is entirely preventable, and losses from cold may also be greatly lessened. The other factors are more difficult to control, but losses can be greatly minimized by intelligent care and attention. The losses shown in Tables IV and V unquestionably considerably understate the average loss, because they represent in the main the experience of the better beekeepers. Those who keep bees housed in kegs, thin store boxes, sections of hollow logs (gums), and similar receptacles, giving them no attention beyond "robbing" them annually of their honey, often at the most inopportune time for the bees, leaving no reserve of food to carry the colony through periods of summer drought and winter cold, and lacking knowledge of the nature and cure of the diseases and other ills that occasionally afflict bees, are naturally the ones to suffer the most severe losses, and such keepers are not as a rule among those whose reports are included in these tables.

While the losses under such conditions are very severe, poor beekeeping is tending to its own correction, as brood diseases, once they attain a foothold in a community, soon eliminate the inefficient and careless beekeepers by eliminating their bees, while the informed and attentive apiarist is able to control these diseases, though sometimes only through the expenditure of much time, effort, and expense.

Losses are frequently reported as being caused by the bee moth (wax moth), but it is well known to experienced beekeepers that these insects are unable to cause serious injury to strong colonies. In weak or dying colonies, where the bees are unable to care for and protect the comb, the moths deposit eggs in the hive and its contents are rapidly destroyed by their larva. Ants, to the contrary, can and frequently do destroy colonies, particularly in the South. Skunks and mice occasionally ruin colonies.

TABLE VI.—*Honey production: Annual yields per colony.*

State.	1899[1]	1909[1]	1913	1914	1915	1916	1917	Average 5 years, 1913–17.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Maine	18	15	38	30	36	52	35	38
New Hampshire	16	14	27	30	48	38	38	36
Vermont	14	16	33	20	35	38	42	34
Massachusetts	13	13	31	22	30	36	26	29
Rhode Island	17	11	45	40	35	36	55	42
Connecticut	11	15	35	28	26	33	37	32
New York	18	20	37	22	59	65	40	45
New Jersey	12	15	40	12	31	66	25	35
Pennsylvania	16	15	45	28	34	54	33	39
Delaware	10	10	21	20	30	36	22	26
Maryland	11	13	40	25	22	46	30	33
Virginia	12	13	38	35	47	32	33	37
West Virginia	15	14	20	25	33	25	33	27
North Carolina	10	10	25	28	42	23	30	30
South Carolina	9	9	25	18	23	35	35	27
Georgia	9	7	30	30	32	33	44	34
Florida	17	19	50	42	65	85	86	66
Ohio	13	10	50	23	22	60	30	37
Indiana	14	8	60	25	26	62	49	44
Illinois	16	9	60	17	44	81	33	47

[1] 1899 and 1909 deduced from United States Census Reports, 1913–1917, based on reports to Bureau of Crop Estimates from honey producers.

TABLE VI.—*Honey production: Annual yields per colony*—Continued.

State.	1899	1909	1913	1914	1915	1916	1917	Average 5 years, 1913–17.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Michigan	21	22	50	37	50	65	43	49
Wisconsin	25	23	60	40	63	69	56	58
Minnesota	22	17	60	35	51	57	56	52
Iowa	17	15	65	25	66	82	46	57
Missouri	15	10	30	8	35	75	26	35
North Dakota	27	22	....	....	72	40	95	69
South Dakota	24	21	50	25	48	84	53	52
Nebraska	17	12	50	30	51	96	49	55
Kansas	13	8	25	20	35	60	46	37
Kentucky	13	10	40	25	40	53	57	43
Tennessee	11	10	30	28	25	31	29	29
Alabama	9	7	35	28	39	48	35	37
Mississippi	11	8	35	33	29	31	43	34
Louisiana	12	11	35	35	30	42	52	39
Texas	12	13	35	55	37	45	12	37
Oklahoma	9	7	35	25	29	39	36	33
Arkansas	13	10	30	20	25	29	33	27
Montana	11	26	35	62	63	65	95	64
Wyoming	19	30	75	70	50	60	89	69
Colorado	29	32	60	43	36	68	46	51
New Mexico	23	44	50	55	40	59	38	48
Arizona	49	43	70	60	70	55	65	64
Utah	38	43	70	65	57	33	106	66
Nevada	31	42	75	40	90	60	44	62
Idaho	20	46	55	56	70	50	72	61
Washington	17	15	45	40	57	45	61	50
Oregon	18	18	40	35	35	30	58	40
California	28	51	36	75	72	62	57	60
United States	14.9	15.9	40.6	32.2	42.3	52.8	40.3	41.6

YIELDS OF HONEY PER COLONY.

Dividing the total production of honey for the years 1899 and 1909 by the numbers of colonies of bees at the beginning of the seasons of 1900 and 1910, respectively, using in both cases figures reported by the United States Census, we secure approximate yields for the two years of about 15 and 16 pounds, respectively. But the yields thus deduced are much below the facts. The census enumerators have difficulty in securing figures for production in a previous year because many people have failed to keep records, or because bees have changed hands and the new holders know nothing of their performance the past season. Only about half those reporting colonies of bees reported any honey production. The figures for the different States are shown in Table VI. The returns of the reporters of the Bureau of Crop Estimates indicate yields much higher, being for the five years, 1913 to 1917, inclusive, 40.6, 32.2, 42.3, 52.8, and 40.3 pounds, respectively. The figures by States are shown in comparison with the census averages in Table VI. These figures, however, represent to a considerable extent the production of the colonies belonging to the reporters, which would naturally be above the average, because the reporters are in the main producers of honey on a commercial scale, using modern methods and giving proper attention to the bees, with the natural result of increased yields. They represent also, in large proportion, beekeepers who are not farmers. The latter, usually handling bees as a side line, are able to give them attention only when their main occupations are not pressing. Unfortunately, general farm work is usually pressing at the time when bees must have attention if good honey crops are to be secured. It will be seen by reference to Table VI that the highest yields, year by year, are secured in the Western States, including those of the Pacific coast, and especially California, the North Central group, particularly those of the northern tier, the Middle Atlantic group, Florida and Texas. The Southeastern States possess potential resources for heavy honey production, but modern equipment and practices have yet to be generally introduced there.

Table VII.—*Honey production.*

(Unites States Census.)

State.	Honey produced in year stated.					
	1859	1869	1879	1889	1899	1909
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Maine	314,685	155,640	198,499	260,481	200,080	112,051
New Hampshire	125,142	56,944	87,886	112,114	89,260	65,038
Vermont	212,150	142,932	221,729	379,096	182,278	160,283
Massachusetts	59,125	25,299	49,397	90,929	109,050	96,802
Rhode Island	5,261	6,290	8,397	13,740	28,450	14,221
Connecticut	62,730	32,158	100,378	130,632	122,960	145,722
New York	2,369,751	896,286	2,088,845	4,281,964	3,422,497	3,191,733
New Jersey	185,925	60,636	131,342	160,310	174,250	152,072
Pennsylvania	1,402,128	796,989	1,415,093	2,453,424	2,526,202	1,840,360
Delaware	66,137	33,151	76,234	66,468	101,410	62,777

TABLE VII.—*Honey production*—Continued.

State.	Honey produced in year stated.					
	1859	1869	1879	1889	1899	1909
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Maryland	193,354	118,938	283,752	301,157	306,788	306,367
District of Columbia	510	....	1,723	341	530	3,657
Virginia	1,431,591	505,239	1,090,451	1,531,147	1,708,320	1,344,360
West Virginia	....	376,997	833,564	1,218,686	1,673,120	1,550,739
North Carolina	2,055,969	1,404,040	1,591,590	2,373,560	2,477,800	1,809,127
South Carolina	526,077	194,253	354,350	856,688	872,590	653,119
Georgia	953,915	610,877	1,056,034	1,757,758	1,650,745	884,662
Florida	115,520	50,884	211,943	562,986	677,540	747,832
Ohio	1,459,601	763,124	1,626,847	2,894,059	1,980,530	1,001,179
Indiana	1,224,489	395,278	967,581	2,106,817	1,681,554	687,097
Illinois	1,346,803	1,547,178	1,310,806	4,602,941	2,961,080	1,428,640
Michigan	769,282	280,325	1,028,595	2,487,134	2,099,460	2,507,810
Wisconsin	207,294	299,341	813,806	3,515,761	2,677,100	2,153,819
Minnesota	34,285	92,606	234,054	1,160,390	986,446	976,262
Iowa	917,877	853,213	1,310,138	6,813,412	2,539,784	2,374,080
Missouri	1,585,983	1,156,444	721,080	4,492,178	3,018,929	2,105,815
North Dakota	....	[1]110	[1]6,180	990	7,530	11,084
South Dakota				55,833	49,320	139,714
Nebraskaa	5,843	28,114	86,645	746,212	866,200	527,868
Kansas	16,944	110,827	201,034	890,913	1,187,569	609,785
Kentucky	1,768,692	1,171,500	1,500,565	2,310,615	2,681,720	1,558,670
Tennessee	1,519,390	1,039,550	2,130,689	2,284,155	2,404,550	1,468,123
Alabama	47,233	320,674	841,535	1,824,286	1,930,410	891,954
Mississippi	708,237	199,581	382,560	822,673	1,048,490	559,012
Louisiana	255,481	37,646	168,441	271,962	426,490	340,134
Texas	594,273	275,169	761,225	3,286,386	4,780,204	3,093,097
Oklahoma	....	....	....	2,800	[2]172,640	140,234
Arkansas	806,327	276,824	1,012,721	1,111,246	1,405,320	913,515
Montana	....	....	....	20	19,940	163,510
Wyoming	....	....	....	350	19,220	138,924
Colorado	....	....	8,340	390,906	1,732,630	2,306,492
New Mexico	....	....	450	21,470	139,998	439,528
Arizona	....	....	650	126,124	930,420	1,025,282
Utah	....	575	87,331	479,158	1,292,118	1,138,091
Nevada	....	363	24,296	88,557	178,650	354,905
Idaho	....	....	50	37,146	379,450	1,011,068
Washington	5,256	25,636	20,005	156,435	530 790	503,580
Oregon	821	66,858	122,348	435,028	979,140	839,981
California	12,276	294,326	574,029	3,929,889	3,667,738	10,264,715
United States	23,366,357	14,702,815	25,743,208	63,897,327	61,099,290	54,814,890

[1] Dakota, before division.

[2] Includes Indian Territory.

TOTAL PRODUCTION OF HONEY, BY DECADES, SINCE 1859.

According to the census figures the production of honey in the year 1859, the first in which this inquiry was made, was in round figures 23,000,000 pounds, a very respectable figure compared with the later reports, but unfair in comparison with the figures of recent decades, because of the great increase in the relative number of commercial producers whose crops do not figure in the census returns. In the year 1869 the production was reduced to about 15,000,000 pounds, due no doubt in large part to the general disorganization and loss incident to the Civil War. The year 1879 saw a recovery to 26,000,000 and the record for 1889 was the highest of any year reported by the census, almost 64,000,000 pounds. For 1889, 61,000,000 pounds were reported and for 1909 only 55,000,000. The latter was a year of poor honey production in the Central and Southern States.

The most striking feature of the figures, given by States in Table VII, is the increase in honey production in the Western States and particularly in California, an increase entirely out of proportion to the development of the West in general lines of agriculture, and so great that the Rocky Mountain and Pacific Coast States are shown by the last census, which, however, covered a favorable honey year in the West and a poor one in the Central and Southern States, to have produced substantially one-third of the total honey crop of the United States, California alone producing almost one-fifth.

In the greatest of the honey years recorded by the census, 1889, the figures for some States are quite astonishing from the standards of other years, New York producing over 4,000,000, Illinois and Missouri between 4,000,000 and 5,000,000, and Iowa almost 7,000,000 pounds, this being for New York a third more, for Illinois and Missouri in excess of a half more, and for Iowa more than double, the crop of any other year reported.

TABLE VIII.—*Honey: Form in which produced.*

State.	Form produced.											
	Comb in sections.				Extracted.				Bulk comb, or "chunk."			
	1914	1915	1916	1917	1914	1915	1916	1917	1914	1915	1916	1917
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Maine	80	80	75	81	15	17	15	11	5	3	10	8
New Hampshire	.....	85	90	90	.....	15	5	10	.....	0	5	0
Vermont	66	90	80	82	28	8	14	15	6	2	6	3
Massachusetts	67	87	71	61	32	13	24	34	1	0	5	5
Rhode Island	5	20	.....	10	95	80	.....	85	0	0	.....	5
Connecticut	48	61	55	65	47	29	40	33	5	10	5	2
New York	47	61	58	54	50	39	40	45	3	0	2	1
New Jersey	25	.....	42	41	75	.....	57	59	0	0	1	0
Pennsylvania	65	60	64	44	29	30	29	50	6	10	7	6
Delaware	.....	60	.....	63	.....	30	.....	18	.....	10	.....	19
Maryland	69	85	70	70	22	10	20	25	9	5	10	5
Virginia	87	75	57	72	12	13	23	8	1	12	20	20
West Virginia	.....	.....	53	72	.....	.....	4	5	.....	.....	43	23
North Carolina	.....	34	32	39	.....	17	20	21	.....	49	48	40
South Carolina	.....	40	.....	30	.....	30	.....	40	.....	30	.....	30
Georgia	28	.....	14	23	33	.....	45	46	39	.....	41	31
Florida	11	.....	9	10	88	.....	89	89	1	.....	2	1
Ohio	66	65	59	64	32	32	36	35	2	3	5	1
Indiana	52	64	53	57	36	21	34	37	12	15	13	6
Illinois	42	34	57	51	56	65	39	46	2	1	4	3
Michigan	56	54	56	38	43	46	44	60	1	0	0	2
Wisconsin	41	43	39	35	58	57	59	63	1	0	2	2
Minnesota	36	50	47	38	63	45	52	61	1	5	1	1
Iowa	56	58	52	49	42	40	45	48	2	2	3	3
Missouri	32	34	40	47	38	37	30	36	30	29	30	17
North Dakota	.....	.....	50	.....	.....	.....	50	.....	.....	.....	0	.....
South Dakota	77	62	57	40	22	30	36	55	1	8	7	5
Nebraska	43	36	68	64	42	63	30	35	15	1	2	1
Kansas	67	65	60	61	28	25	23	30	5	10	17	9
Kentucky	49	.....	38	41	33	.....	36	44	18	.....	26	15
Tennessee	31	22	28	36	23	28	27	27	46	50	45	37
Alabama	34	32	25	18	41	42	52	62	25	26	23	20
Mississippi	49	.....	41	46	26	.....	19	32	25	.....	40	22
Louisiana	.....	.....	11	15	.....	.....	40	35	.....	.....	49	50
Texas	4	1	7	9	51	52	55	69	45	47	38	22
Oklahoma	36	37	42	28	17	15	18	23	47	48	40	49
Arkansas	25	.....	41	35	15	.....	8	18	60	.....	51	47
Montana	.....	70	63	67	.....	27	35	29	.....	3	2	4
Wyoming	92	97	77	46	8	3	16	54	0	0	7	0
Colorado	67	70	63	62	30	30	31	37	3	0	6	1

TABLE VIII.—*Honey: Form in which produced*—Continued.

State.	Form produced.											
	Comb in sections.				Extracted.				Bulk comb, or "chunk."			
	1914	1915	1916	1917	1914	1915	1916	1917	1914	1915	1916	1917
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
New Mexico	31	.....	42	35	61	.....	40	47	8	.....	18	18
Arizona	6	10	0	5	94	90	100	95	0	0	0	0
Utah	17	15	.....	10	83	85	.....	90	0	0	.....	0
Nevada	.....	.....	30	20	.....	.....	70	80	.....	.....	0	0
Idaho	47	60	39	40	51	37	58	60	2	3	3	0
Washington	46	32	37	25	54	68	59	72	0	0	4	3
Oregon	64	48	.....	60	34	52	.....	31	2	0	.....	9
California	18	17	17	15	79	82	81	82	3	1	2	3
United States	41.7	40.0	38.1	37.9	42.1	41.0	43.8	48.4	16.2	19.0	18.1	13.7

FORM OF HONEY PRODUCED.

Honey is produced in three principal forms: First, comb-honey in 1-pound sections, as commonly retailed; second, extracted or liquid honey, ordinarily removed from the comb by means of a centrifugal machine, although sometimes by crushing the comb and draining, or by pressing it, although this last procedure is likely to produce an inferior product; third, "bulk" or "chunk" honey, the comb honey more or less broken and mixed with the liquid honey. A pleasing form of "chunk" honey is that prepared in large quantities in Texas and some other States, choice comb being cut from the frames, packed in tin pails or glass jars and the remaining space in the container filled with extracted honey from the same source.

According to the reports to the bureau, which are shown in detail by States and for the four years, 1914 to 1917, inclusive, in Table VIII, the proportion of comb and "chunk" honey shows a tendency to decrease, and of extracted to increase, the change from "chunk" and to extracted being particularly noticeable in 1917, reflecting an endeavor on the part of the producers to increase the production of honey in view of the threatened sugar shortage. Bees are ordinarily able to produce a larger quantity of honey if they are not compelled to build comb for it, and by emptying the combs and replacing them in the hive, the bee is able in periods of heavy nectar secretion to proceed immediately to the storage of more honey.

By reference to Table VIII it will be seen that the greater proportion of section comb honey is produced in the North Atlantic, the North Central and a few Western States, practically all of the "bulk" or "chunk" honey in the Southeastern and South Central States, and the larger proportion of the extracted or liquid form in the North Central and Western States. The comb honey is most in demand for the home and fancy trade and for seasonal consumption, much the greater proportion being consumed within the first six months after its production, the extracted as a staple product, being stored and handled throughout the year and entering into interstate and foreign commerce, and the "bulk" or "chunk" honey for home consumption, finding only a limited and local market. The present year shows a decided drift in the Southern States away from the production of "chunk" honey and toward comb in sections, being a transition stage accompanying the gradual introduction of improved methods in the States where "bulk" honey has hitherto been a, if not the, principal form.

It should be borne in mind that in the Southeastern States the less progressive elements of the industry, which are more largely devoted to the production of "chunk" honey, are but lightly represented in these returns and that the production of that form is probably in much larger relative proportion than here shown, while comb-honey is overstated, both in these States and in some of heavy commercial production, such as California, where the extracted forms a larger proportion than indicated.

TABLE IX.—*Honey: Color.*

State.	Form and color.															
	White.				Light amber.				Amber.				Dark.			
	Comb.	Extracted.	Bulk or "chunk."	Total.	Comb.	Extracted.	Bulk or "chunk."	Total.	Comb.	Extracted.	Bulk or "chunk."	Total.	Comb.	Extracted.	Bulk or "chunk."	Total.
	P.c.	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*
Maine	49	7	4	60	13	2	2	17	10	1	1	12	9	1	1	11
New Hampshire	56	....	....	56	24	....	....	24	16	....	....	16	4	....	....	4
Vermont	59	6	3	68	15	5	....	20	3	3	....	6	5	1	....	6
Massachusetts	14	2	1	17	12	12	1	25	19	16	2	37	16	4	1	21
Rhode Island	7	....	....	7	....	15	....	15	3	37	....	40	....	33	5	38
Connecticut	12	1	....	13	18	6	....	24	19	18	2	39	16	8	....	24
New York	32	23	1	56	7	5	....	12	3	6	....	9	12	11	....	23
New Jersey	16	10	....	26	8	22	....	30	9	21	....	30	8	6	....	14
Pennsylvania	18	16	2	36	3	3	1	7	6	10	1	17	17	21	2	40
Delaware	20	10	7	37	20	1	....	21	10	2	....	12	13	5	12	30
Maryland	16	8	....	24	14	13	4	31	14	12	1	27	13	5	....	18
Virginia	32	1	7	40	19	4	4	27	10	3	5	18	11	....	4	15
West Virginia	36	3	8	47	14	....	2	16	13	2	7	22	9	....	6	15
North Carolina	11	....	17	28	11	6	10	27	8	4	7	19	9	11	6	26
South Carolina	....	....	9	9	14	8	....	22	10	32	....	42	6	....	21	27
Georgia	5	5	1	11	14	10	13	37	....	12	7	19	4	19	10	33
Florida	5	15	....	20	1	40	....	41	2	20	1	23	....	16	....	16
Ohio	43	21	....	64	11	9	....	20	7	3	1	11	3	2	....	5
Indiana	30	18	1	49	17	12	3	32	8	6	1	15	2	1	1	4
Illinois	21	10	1	32	15	23	1	39	10	13	1	24	5	....	....	5
Michigan	32	52	1	85	3	3	1	7	2	3	....	5	1	2	....	3
Wisconsin	30	50	....	80	3	10	1	14	1	2	1	4	1	1	....	2
Minnesota	28	38	1	67	4	13	....	17	3	7	....	10	3	3	....	6
Iowa	35	28	1	64	9	12	....	21	4	7	1	12	1	1	1	3
Missouri	12	1	2	15	16	9	11	36	8	25	3	36	11	1	1	13
North Dakota	....	12	21	33	1	37	....	38	....	25	....	25	....	....	4	4
South Dakota	27	35	2	64	10	18	1	29	2	2	1	5	1	....	1	2
Nebraska	28	14	....	42	20	8	....	28	12	7	1	20	4	6	....	10
Kansas	32	10	2	44	11	13	2	26	11	5	1	17	7	2	4	13
Kentucky	15	28	6	49	11	14	4	29	13	1	3	17	2	1	2	5
Tennessee	8	....	18	26	8	10	7	25	10	17	11	38	10	....	1	11
Alabama	7	13	4	24	11	23	8	42	....	19	6	25	....	7	2	9
Mississippi	20	6	14	40	11	20	6	37	9	4	1	14	6	2	1	9
Louisiana	5	7	12	24	5	15	31	51	3	8	5	16	2	5	2	9
Texas	5	21	7	33	3	26	9	38	....	17	6	23	1	5	....	6
Oklahoma	7	1	10	18	10	12	30	52	7	7	6	20	4	3	3	10
Arkansas	6	5	18	29	23	9	16	48	4	3	6	13	2	1	7	10
Montana	46	16	1	63	14	10	....	24	5	3	....	8	2	3	....	5
Wyoming	46	54	....	100	....	....	....	....	....	....	....	....	....	....	....	....
Colorado	35	19	1	55	20	15	....	35	5	3	....	8	2	....	....	2

TABLE IX.—*Honey: Color*—Continued.

State.	Form and color.															
	White.				Light amber.				Amber.				Dark.			
	Comb.	Extracted.	Bulk or "chunk."	Total.	Comb.	Extracted.	Bulk or "chunk."	Total.	Comb.	Extracted.	Bulk or "chunk."	Total.	Comb.	Extracted.	Bulk or "chunk."	Total.
	P.c.	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*	*P.c.*
New Mexico	13	13	8	34	8	15	8	31	8	17	2	27	6	2	....	8
Arizona	5	24	....	29	....	49	....	49	....	22	....	22	....	....	....	....
Utah	9	75	....	84	1	15	....	16	....	....	....	....	....	....	....	....
Nevada	16	75	....	91	1	5	....	6	2	....	....	2	1	....	....	1
Idaho	31	42	....	73	6	18	....	24	2	....	....	2	1	....	....	1
Washington	14	37	....	51	11	25	2	38	....	8	1	9	....	2	....	2
Oregon	42	11	3	56	6	20	....	26	9	1	6	16	2	....	....	2
California	9	36	2	47	4	38	1	43	1	6	....	7	1	2	....	3
United States	19.0	19.3	4.5	42.8	9.4	15.7	4.4	29.5	5.0	9.2	2.9	17.1	4.5	4.2	1.9	10.6

COLOR OF HONEY.

An inquiry on November 1, 1917, concerning the per cent of surplus honey produced according to color, shows for the United States 42.8 per cent of white honey, 29.5 per cent of light amber, 17.1 per cent of amber, and 10.6 per cent of dark. The details by States are shown in Table IX. The figures of the total per cent of each color, are more accurate than those showing color in detail according to the form of honey produced.

TABLE X.—*Honey: Disposition of crops.*

State.	Usual disposition.					
	Used at home.			Sold to outside markets.		
	1915	1916	1917	1915	1916	1917
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Maine	75	94	97	25	6	3
New Hampshire	....	83	77	....	17	23
Vermont	5	78	74	95	22	26
Massachusetts	94	92	84	6	8	16
Rhode Island	100	100	98	....	....	2

TABLE X.—*Honey: Disposition of crops*—Continued.

State.	Usual disposition.					
	Used at home.			Sold to outside markets.		
	1915	1916	1917	1915	1916	1917
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Connecticut	83	75	86	17	25	14
New York	45	58	67	55	42	33
New Jersey	96	53	81	4	47	19
Pennsylvania	75	77	76	25	23	24
Delaware	....	80	85	....	20	15
Maryland	80	67	78	20	33	22
Virginia	75	80	88	25	20	12
West Virginia	....	90	90	....	10	10
North Carolina	51	69	98	49	31	2
South Carolina	98	97	75	2	3	25
Georgia	75	78	77	25	22	23
Florida	42	60	62	58	40	38
Ohio	75	83	82	25	17	18
Indiana	97	91	94	3	9	6
Illinois	59	63	80	41	37	20
Michigan	54	65	68	46	35	32
Wisconsin	58	68	68	42	32	32
Minnesota	55	72	78	45	28	22
Iowa	65	70	87	35	30	13
Missouri	95	82	96	5	18	4
North Dakota	....	100	100	....	....	....
South Dakota	85	86	86	15	14	14
Nebraska	64	85	85	36	13	15
Kansas	99	84	90	1	16	10
Kentucky	33	57	68	67	43	32
Tennessee	88	82	90	12	18	10
Alabama	55	55	52	45	45	48
Mississippi	71	87	66	29	13	34
Louisiana	35	56	70	65	44	30
Texas	35	55	68	65	45	32
Oklahoma	99	91	91	1	9	9
Arkansas	92	90	93	8	10	7
Montana	67	68	67	33	32	33
Wyoming	6	75	42	94	25	58
Colorado	23	35	45	77	65	55
New Mexico	42	53	41	58	47	59
Arizona	36	52	31	64	48	69
Utah	32	57	43	68	43	57
Nevada	....	10	33	....	90	67
Idaho	23	52	34	77	48	66
Washington	54	40	68	46	60	32
Oregon	92	77	56	8	23	44
California	13	14	23	87	86	77
United States	60.8	64.0	71.1	39.2	36.0	28.9

MARKET.

The proportion of the crop consumed at home or sold locally and that shipped to outside markets, not necessarily wholesale, is shown in Table X for the three years 1915, 1916, and 1917. It may be observed that 39.2 per cent was shipped to outside markets in 1915, 36.0 per cent in 1916, and but 28.9 per cent in 1917, the decreasing percentage released for the general market in 1917 being due partly to a moderate crop, which, even if the home consumption remained the same, would require a larger percentage of the crop, and partly to the shortage in the sugar supply, which created a keener home demand for honey. The smaller percentage of the smaller 1917 crop sent to outside markets, if contrasted with the larger percentage retained of the larger crop of 1916, indicates only about 60 per cent as much honey disposed of through the main trade channels.

TABLE XI.—*Value of exports of domestic honey from the United States, 1911–1917.*

Country of destination.	Fiscal year ending June 30—							
	1911	1912	1913	1914	1915	1916	1917	1918, 6 months ending Dec., 1917.
Europe:	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*
Denmark	....	....	....	....	14,375	8,854	10,615	75,525
France	....	189	3,326	8,090	2,114	868	20,678	....
Germany	38,769	134,175	107,069	75,233	10,200	....	....	....
Italy	....	221	....	173	2,378	....	13,483	500,354
Netherlands	5,232	12,835	3,039	11,398	6,991	11,122	2,000	....
Norway	....	....	....	....	....	....	4,600	....
Sweden	....	....	....	....	....	....	8,300	....
United Kingdom: England	8,267	27,573	16,369	3,969	51,713	123,931	596,626	625,037
North America: Canada	20,275	23,666	43,276	27,384	14,930	38,398	53,614	36,589
Oceania, Philippine Islands	2,838	3,519	1,701	2,495	2,149	2,635	2,575	2,437
All other	6,268	10,474	7,472	6,927	9,188	66,679	23,648	14,945
Total	81,649	212,652	182,252	135,669	114,038	252,487	736,139	1,254,887

TABLE XII.—*Honey: Imports into United States, fiscal years ending June 30, 1911–1917.*

Country of origin.	1911	1912	1913	1914	1915	1916	1917	1918, 6 months ending Dec., 1917.
VALUES.								
Insular possessions:	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*
Hawaii	52,004	35,973	57,450	33,992	35,536	53,163	62,462	104,946
Porto Rico	17,904	42,251	59,721	90,976	94,895	82,272	103,388	219,843
Total value of shipments to United States of honey from insular possessions	69,908	78,224	117,171	124,968	130,431	135,435	165,850	324,789
Foreign countries:								
Mexico	28,420	20,100	27,702	20,443	42,466	10,900	10,986	11,385
Cuba	26,462	30,225	30,720	6,880	61,334	67,959	198,939	70,374
Dominican Republic	272	4,162	2,156	2,980	14,566	7,476	40,182	119,159
Haiti	4,614	5,832	2,457	1,456	2,387	2,413	20,443	15,262
All other	3,174	2,365	5,682	6,906	4,090	8,713	18,767	39,773
Total value of imports of foreign honey into United States	62,942	62,684	68,717	38,665	124,843	97,461	289,317	255,953
Total value of honey from insular possessions and foreign countries	132,850	140,908	185,888	163,633	255,274	232,896	455,167	580,742
QUANTITIES.								
Foreign countries:	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
Mexico	48,171	34,051	46,028	43,227	92,876	29,002	22,462	16,816
Cuba	50,131	54,226	56,899	15,094	164,042	152,971	296,983	56,788
Dominican Republic	634	8,528	4,638	5,304	33,571	18,585	61,156	103,937
Haiti	10,812	16,261	4,384	2,453	7,309	5,067	26,266	15,951
All other	2,805	1,974	4,322	9,001	6,167	15,599	20,783	33,600
Total quantities of foreign honey imported	112,553	115,040	116,271	75,079	303,965	221,224	427,650	227,092
Average value per gallon ... cents	55.9	54.5	59.1	51.5	41.1	44.1	67.7	112.7

EXPORTS AND IMPORTS.

In Table XI is shown the exports of domestic honey from the United States for the past seven fiscal years, ending June

30, 1917, representing in the main in each case the movement of the crop of the preceding year. Unfortunately, the quantities have not been reported in the trade statistics until the present year. That shipped abroad is almost all extracted honey (some comb honey going to Canada). The price for extracted honey of good quality, such as comprises most of this country's exports, ranged in the neighborhood of 9 cents per pound until the fiscal years 1915 and 1916, when it fell to as low as 7 cents. In 1917 it rebounded to the previous figures and above, and this fiscal year (1918) it has reached to above 15 cents per pound. Some impression may be gained from these figures of the quantity of honey exported, ranging probably from one to two million pounds annually up to 1915, between three and four millions in 1916, and six and seven millions in 1917. For the first half of 1918 they are reported at almost eight million pounds. Prior to the outbreak of the great war more than half of the exports were regularly consigned to Germany. In 1914 these exports fell off somewhat, and in 1915, after small shipments, they ceased. In 1915 a very great increase occurred in the shipments to England, and in 1916 they doubled the large shipments of 1915, while for the year ending June 30, 1917, they probably treble the shipments of 1916. Six months of the fiscal year 1918 show shipment values compared with all of 1917 slightly greater for England, and almost fourfold greater to France, while the formerly insignificant shipments to Italy have leaped to a value of over half a million dollars.

The imports of foreign honey into the United States, aggregating prior to the war something over 100,000 gallons annually, principally from Mexico, Cuba, and other West Indian and Central American countries, are shown in Table XII for the years 1911 to 1917, including both values and quantities. Mexico was our principal source of supply until 1914, with Cuba a close second, but in 1915, while the Mexican supply increased somewhat, the Cuban supply, having its European outlet closed, more than doubled any previous year. In 1916 the Mexican shipments fell off very markedly, while those from Cuba and other countries to the south continued to increase, and in 1917 they further increased to a total of 427,650 gallons, almost double that of any previous year except 1915, the year in which the war first diverted shipments to our shores. These imports reached 227,092 gallons during the first half of 1918, indicating a probable further material increase in the total this year. This imported honey is largely amber and dark types, used hitherto mostly for baking purposes, and usually competes only with similar grades of home-grown honeys. Most of the imports are to New York.

Honey is also imported into the United States from the island possessions of Hawaii and Porto Rico. The Hawaiian imports are partly of a first-class honey, derived from the Algaroba, a leguminous shrub tree similar to the mesquite of the Southwest, and partly from honeydew, and have ranged in value from about $35,000 to $60,000. For the first six months of 1918 (to Dec. 31, 1917) the value increased by two-thirds over the total for 1917, representing the receipt of 1,445,000 pounds of honey. Those of Porto Rico, principally from the guava and guama, both leguminous trees, and of fair quality, have mounted rapidly from a value of $17,904 in 1911, the first year of substantial shipments, to $103,388 in 1917. The value has already reached $219,843 for the first half of 1918, representing almost 2,000,000 pounds of honey.

SUPPLY AND PRICES.

The conditions obtaining years ago in connection with honey production tended to the handling of honey rather on the basis of a seasonal product than as a staple food for use throughout the year.

The bulk of the honey was produced by farmers as a side line, the bees being given little attention and the honey being produced at relatively little expense. The crop was marketed at low prices in the autumn, and stocks were usually exhausted by the late winter. There was little demand and practically no supply during the spring and early summer.

Honey is now handled in a large way as a staple food product, and this has been in part brought about and the industry is being now largely shaped, through the influence of commercial beekeeping, the production of honey as a principal occupation, which calling, while exceedingly ancient, has had a rapid and interesting development during recent years. The fact that bee diseases drive out of

TABLE XIII.—*Honey prices.*

State.	Average September prices per pound paid producers for all grades at local markets.										Average prices per pound for white honey in wholesale lots, 1 ton or over.					
	Comb.					Extracted.					July 1, 1917.		Sept. 1, 1917.		Nov. 1, 1917.	
	1913	1914	1915	1916	1917	1913	1914	1915	1916	1917	Comb.	Ext.	Comb.	Ext.	Comb.	Ext.
	Cts.	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*
Maine	19	19	20	20	21	13	......	......	19	......	25	20	21	16	22	18
New Hampshire	20	20	20	20	21	20	20	......	22	......	20	......	31	18	23	......
Vermont	18	18	17	18	20	20	18	16	......	16	20	......	18	13	19	14
Massachusetts	18	19	20	19	22	18	23	......	......	......	22	......	22	20	27	......
Rhode Island	19	25	......	......	......	......	25	......	......	......	......	14	......	......	......	......
Connecticut	20	20	18	18	23	15	15	16	15	19	22	16	22	17	26	20
New York	14	15	14	15	16	11	14	14	13	12	16	11	16	13	17	14
New Jersey	18	17	15	13	20	16	18	......	......	......	22	20	18	......	21	16
Pennsylvania	15	16	16	16	18	9	10	11	10	14	19	14	18	14	18	14
Delaware	15	15	15	20	......	......	......	......	......	......	14	14	16	18	13	......
Maryland	18	19	18	15	16	12	......	23	......	......	18	15	16	10	18	16
Virginia	13	13	13	15	17	13	13	13	16	18	18	21	17	......	17	18
West Virginia	17	18	18	20	20	14	15	15	15	18	22	16	20	20	20	......
North Carolina	14	14	13	14	18	14	13	14	14	18	18	17	20	17	19	14
South Carolina	13	12	12	12	15	15	15	14	15	19	15	......	15	......	16	......
Georgia	12	12	12	12	15	13	13	13	12	16	16	15	16	12	19	10
Florida	15	13	13	13	15	......	9	10	9	10	14	9	15	9	13	10
Ohio	16	15	16	16	18	12	13	14	15	17	17	12	17	12	19	14
Indiana	16	17	18	17	20	17	16	17	15	21	19	14	19	15	20	16
Illinois	15	15	16	16	17	12	14	15	12	14	18	13	17	14	20	14

Michigan	14	14	14	14	17	10	10	10	10	12	15	11	18	13	18	15
Wisconsin	14	14	14	14	16	10	10	10	10	12	14	11	19	12	17	14
Minnesota	15	15	15	15	16	12	14	13	12	14	18	14	17	12	18	13
Iowa	16	14	15	14	17	14	12	12	11	15	16	11	17	13	18	14
Missouri	15	15	15	15	17	13	15	12	12	15	16	12	19	15	20	......
North Dakota	18	15	15	19	25	14	12	12	12	19	......	......	......	......	......	......
South Dakota	15	15	15	14	18	13	15	14	14	16	20	15	14	12	15	14
Nebraska	15	15	15	16	17	13	12	12	11	13	18	14	15	13	17	15
Kansas	15	15	14	14	17	12	11	11	11	12	16	13	17	14	18	16
Kentucky	14	15	14	16	18	15	14	13	12	15	18	12	17	14	18	16
Tennessee	14	14	13	14	16	15	14	13	15	16	20	17	18	16	18	20
Alabama	11	11	11	11	13	12	12	12	12	13	15	13	16	13	12	12
Mississippi	12	11	11	10	14	10	12	12	12	15	19	19	15	12	13	14
Louisiana	13	......	13	20	15	12	......	13	10	11	15	......	15	......	15	......
Texas	12	12	11	10	15	11	10	10	10	12	......	10	13	12	14	13
Oklahoma	15	16	15	15	20	13	11	12	14	17	20	15	21	12	20	20
Arkansas	12	12	12	12	15	12	11	12	12	15	16	15	15	12	15	12
Montana	13	12	13	12	18	11	10	12	10	15	14	11	16	13	15	14
Wyoming	12	14	12	12	......	10	10	11	10	......	12	......	......	12	16	13
Colorado	12	12	13	12	15	10	8	7	8	14	12	10	15	13	15	12
New Mexico	12	11	12	12	15	13	10	......	12	13	14	10	13	11	14	10
Arizona	12	10	13	10	......	7	9	......	16	......	......	......	15	10	14	10
Utah	9	11	10	11	12	7	7	7	7	10	......	......	12	10	12	12
Nevada	13	......	14	12	......	7	......	7	7	......	......	......	13	12	14	13
Idaho	12	12	11	12	15	8	9	10	10	14	12	8	15	12	14	12
Washington	15	14	13	13	15	11	9	12	10	13	14	......	15	11	16	11
Oregon	12	12	12	12	15	12	11	9	......	15	......	......	14	13	12	12
California	13	13	11	12	15	9	8	6	7	11	14	12	17	12	14	12
United States	13.8	13.7	13.3	13.7	16.3	11.9	11.2	10.7	11.4	14.2	16.5	13.1	16.5	13.2	17.0	14.0

business the untrained and indifferent beekeeper, who is unable to successfully combat them, opens the field to the man capable of overcoming them, who is usually also a deeper student of the entire subject of bees and of their care and protection, better informed on sources of nectar, dates of flow, etc., and is therefore able to handle the bees with a view to maximum honey production. But as honey becomes a main crop, and its sale the main source of income, closer attention is drawn to cost of production. Modern equipment must be purchased and the product prepared in an attractive manner. The commercial producer is not able to sell his product for less than the actual expense of production and continue in the business, as is the practice with many who produce honey in a desultory way.

The present exceptional demand, due to the shortage of sugar arising from war conditions, has raised the price of honey to a figure unheard of during the present generation and may be expected to result in some increase in beekeeping, although the general high range of prices, which affects all products that the honey producer himself must purchase, to a considerable extent offsets this increase in the price of his own product.

If the importance of honey as a food, particularly valuable to children and to those with delicate digestions in lieu of the less readily digestible sugars, candies, and confections, and its high merit for use in preparing savory cakes and other foods, as well as in giving palatability to humble articles of fare, should be properly realized and a demand established at permanently adequate prices, a very great increase in the country's supply of this delicious food product might be realized through the inducement thus afforded to competent persons to engage in honey production on a commercial scale.

The usual prices received by producers at their local markets in the month of September, being the rate for small wholesale lots and including many retail quotations, as reported to the Bureau of Crop Estimates by a list of local dealers, are shown in Table XIII, and are fairly representative of the average range of prices shown by the reports for other months of the year. The small effect upon these prices of the varying production of honey in different years is noteworthy, as is the sudden increase in the present year, which had its beginning in the latter part of 1916. In connection with these, wholesale figures are also shown, being those quoted by the special list of honey producers, of prices received in 1917 for honey in quantities of 1 ton or over, the extracted in barrels or 5-gallon tin cans and comb in cases of twenty-four 1-pound sections. These last figures probably contain some quotations for quantities of less than 1 ton, but are believed to fairly represent the strictly wholesale prices for delivery at local shipping points. The narrow margin between the former figures, which verge closely upon the average price when sold by producers at retail, and the wholesale price, is striking, reflecting the slowness with which most honey producers, disposing of and often retailing their products in local communities, take note of the prevailing wholesale prices in the main markets, many still adhering to their traditional retail figure when practically the same price might be obtained wholesale for their entire product.

TABLE XIV.—*Principal plants furnishing nectar and pollen; average dates of beginning and ending of blooming periods.*

State.	Clovers.					
	Alfalfa.		White and Alsike.		Sweet (*Melilotus*).	
	Begin.	End.	Begin.	End.	Begin.	End.
Maine			June 18	Aug. 1	July 20	Aug. 20
New Hampshire			June 15	July 20		
Vermont			June 13	July 16		
Massachusetts			June 10	July 15	July 10	Aug. 25
Rhode Island			June 10	July 18		
Connecticut			June 7	July 8	July 8	Aug. 25
New York			June 15	July 15	July 12	Aug 21
New Jersey			June 8	July 10		
Pennsylvania			June 6	July 15		
Delaware						
Maryland			May 20	July 5	June 10	Aug. 10
Virginia			May 22	July 1	May 10	Aug. 1
West Virginia			May 20	June 30		
North Carolina			May 10	June 30		
South Carolina						

TABLE XIV.—*Principal plants furnishing nectar and pollen; average dates of beginning and closing of blooming periods*—Continued.

State.	Clovers.					
	Alfalfa.		White and Alsike.		Sweet (*Melilotus*).	
	Begin.	End.	Begin.	End.	Begin.	End.
Georgia						
Florida						
Ohio			May 30	July 14	June 28	Aug. 13
Indiana			May 30	July 10	June 23	Aug. 15
Illinois			May 28	July 10	June 29	Aug. 17
Michigan			June 6	July 14	July 13	Aug. 28
Wisconsin			June 13	July 26	July 24	Sept. 5
Minnesota			June 12	July 18	July 20	Sept. 1
Iowa			June 6	July 15	June 28	Aug. 18
Missouri			May 20	July 1	June 10	July 30
North Dakota						
South Dakota			June 6	July 24	June 26	Aug. 16
Nebraska	June 18	Sept. 1	June 1	Aug. 1	June 26	Aug. 24
Kansas	May 23	Sept. 4	May 18	June 27	June 14	Aug. 10
Kentucky			May 24	July 9	June 8	July 27
Tennessee			May 16	July 3		
Alabama					May 14	July 10
Mississippi			Apr. 15	June 5	May 15	July 10
Louisiana			Apr. 15	June 15		
Texas					May 25	July 25
Oklahoma	May 23	Aug. 29	Apr. 10	June 15	June 2	Aug. 10
Arkansas			May 15	June 25	May 25	July 25
Montana			June 10	July 25	June 15	Aug. 25
Wyoming	June 15	Sept. 1			July 5	Sept. 10
Colorado	June 13	Sept. 1			July 1	Aug. 28
New Mexico					June 18	Sept. 14
Arizona	May 9	Oct. 1			Apr. 1	June 1
Utah	June 28	Sept. 5			July 4	Sept. 7
Nevada	May 20	Oct. 1				
Idaho	June 21	Sept. 6	May 30	Aug. 5	July 16	Sept. 16
Washington	June 16	Sept. 1	June 6	Aug. 21	July 15	Sept. 15
Oregon	June 1	Sept. 15	June 2	Aug. 5	July 10	Sept. 10
California	May 15	Sept. 15				

TABLE XIV.—*Principal plants furnishing nectar and pollen; average dates of beginning and ending of blooming periods*—Continued.

State.	Trees.[1]					
	Deciduous fruit trees.[2]		Basswood (linden).		Gums.[3]	
	Begin.	End.	Begin.	End.	Begin.	End.
Maine	June 1	June 15	July 21	Aug. 2		
New Hampshire						
Vermont	May 15	May 25	July 10	July 24		
Massachusetts	May 13	May 30	July 5	July 25		
Rhode Island						
Connecticut	May 1	June 1	July 10	July 25		
New York	May 9	May 25	July 8	July 20		
New Jersey	Apr. 26	May 21				
Pennsylvania	May 1	May 12	June 30	July 22		
Delaware						
Maryland	Apr. 20	May 15	June 20	June 30		
Virginia	Apr. 13	May 5	June 25	July 5		
West Virginia	Apr. 20	May 10	June 20	July 5		
North Carolina			July 10	Aug. 1	May 1	May 20
South Carolina						
Georgia	Apr. 3	May 5			Apr. 10	May 6
Florida					Mar. 10	Apr. 25
Ohio	Apr. 22	May 9	June 24	July 12		
Indiana	Apr. 19	May 12	June 20	July 5		
Illinois	Apr. 17	May 10	June 21	July 7		
Michigan	May 12	May 28	July 2	July 18		
Wisconsin	May 12	May 20	July 8	July 25		
Minnesota			July 10	July 25		
Iowa	Apr. 29	May 16	July 1	July 15		
Missouri	Apr. 10	Apr. 28	June 12	June 28		
North Dakota						
South Dakota			July 1	July 15		
Nebraska						
Kansas	Apr. 19	May 9	June 8	June 26		
Kentucky	Apr. 12	May 8	June 15	July 1		
Tennessee	Apr. 3	Apr. 28	June 13	June 22		
Alabama	Apr. 10	May 10			Apr. 9	May 10
Mississippi					Apr. 10	May 5
Louisiana					Mar. 25	Apr. 18
Texas	Apr. 15	Apr. 25				

[1] Black mangrove (*Avicennia*), Florida, June 20 to July 25. Cabbage palmetto (*Sabal*), Florida, June 13 to July 15. Saw palmetto (*Serenoa*), Florida, May 10 to June 15. Orange: California, Mar. 22 to May 5; Florida, February to March. Maple: January in south Florida, February in Gulf Coast States, March south of latitude of Maryland and April north of it, and into the first half of May in the northern tier of States.

[2] Principally apple; Georgia, peach, Mar. 1 to Apr. 1.

[3] Tupelo on the Gulf coast blooms in March, and other gums mostly in April.

TABLE XIV.—*Principal plants furnishing nectar and pollen; average dates of beginning and ending of blooming periods*—Continued.

State.	Trees.					
	Deciduous fruit trees.		Basswood (linden).		Gums.	
	Begin.	End.	Begin.	End.	Begin.	End.
Oklahoma	Apr. 25	May 5				
Arkansas	Mar. 25	Apr. 5			Apr. 10	Apr. 20
Montana						
Wyoming						
Colorado	Apr. 23	May 12				
New Mexico	Apr. 10	Apr. 28				
Arizona	Mar. 10	Apr. 15				
Utah	Apr. 20	May 10				
Nevada						
Idaho	May 8	May 31				
Washington	Apr. 15	May 15				
Oregon	Apr. 16	June 16				
California	Feb. 21	Apr. 13				

State.	Trees.					
	Holly (*Ilex opaca*).		Black locust (*Robinia*).		Persimmon.	
	Begin.	End.	Begin.	End.	Begin.	End.
Maine						
New Hampshire						
Vermont						
Massachusetts			June 5	June 15		
Rhode Island						
Connecticut						
New York						
New Jersey						
Pennsylvania			May 25	June 4		
Delaware						
Maryland			May 15	May 25		
Virginia			May 5	May 20		
West Virginia			May 2	May 18		
North Carolina	May 1	May 15	May 10	May 20	May 25	June 15
South Carolina	May 1	May 15				
Georgia	May 2	May 16			Apr. 5	Apr. 28
Florida						
Ohio			May 13	May 26		
Indiana			May 15	May 24		
Illinois						

TABLE XIV.—*Principal plants furnishing nectar and pollen; average dates of beginning and ending of blooming periods*—Continued.

State.	Trees.					
	Holly (*Ilex opaca*).		Black locust (*Robinia*).		Persimmon.	
	Begin.	End.	Begin.	End.	Begin.	End.
Michigan						
Wisconsin						
Minnesota						
Iowa						
Missouri						
North Dakota						
South Dakota						
Nebraska						
Kansas			May 25	June 10		
Kentucky			May 8	May 22		
Tennessee			May 1	May 15	June 1	June 15
Alabama			Apr. 25	May 10	May 6	May 20
Mississippi	Apr. 25	May 21	Apr. 15	May 1	Apr. 16	Apr. 30
Louisiana	Apr. 5	Apr. 20				
Texas						
Oklahoma			May 5	May 15		
Arkansas					May 20	June 5
Montana						
Wyoming						
Colorado						
New Mexico						
Arizona						
Utah						
Nevada						
Idaho						
Washington						
Oregon						
California	June 30	Aug. 20				

State.	Trees—Continued.				Shrubs.[1]	
	Sourwood (*Oxydendrum*).		Tulip poplar (*Liriodendron*).		Gallberry (*Ilex glabra*).	
	Begin.	End.	Begin.	End.	Begin.	End.
Maine						
New Hampshire						
Vermont						
Massachusetts						
Rhode Island						

[1] Mesquite (*Prosopis*): Texas, first flow Apr. 15 to May 15, second flow June 15 to July 15; New Mexico, single flow May 6 to July 1; Arizona, single flow Apr. 15 to May 18; Nevada, single flow Apr. 20 to June 1. Catsclaw (*Acacia greggii*), Texas, Apr. 20 to May 16. Guajilla (*Havardia*), Texas, Apr. 20 to May 25. Sage (*Ramona*), California, Mar. 1 to July 1 (mostly April, May, and June). Wild buckwheat (*Eriogonum*), California, June 10 to Aug. 1. Gallberry (*Ilex glabra*): Florida, Mar. 25 to May 5; Georgia, Apr. 27 to May 28; North Carolina, May 20 to June 13.

TABLE XIV.—*Principal plants furnishing nectar and pollen; average dates of beginning and ending of blooming periods*—Continued.

State.	Trees—Continued.				Shrubs.	
	Sourwood (*Oxydendrum*).		Tulip poplar (*Liriodendron*).		Gallberry (*Ilex glabra*).	
	Begin.	End.	Begin.	End.	Begin.	End.
Connecticut						
New York						
New Jersey			May 10	May 20		
Pennsylvania			May 22	June 6		
Delaware						
Maryland			May 16	May 28		
Virginia	June 23	July 20	May 10	May 20		
West Virginia	June 30	July 25	May 25	June 10		
North Carolina	June 25	July 20	May 20	June 8	May 20	June 13
South Carolina			May 1	May 20		
Georgia	May 25	June 25	Apr. 16	May 10	Apr. 27	May 28
Florida					Mar. 25	May 5
Ohio						
Indiana						
Illinois						
Michigan						
Wisconsin						
Minnesota						
Iowa						
Missouri						
North Dakota						
South Dakota						
Nebraska						
Kansas						
Kentucky			May 15	June 5		
Tennessee	June 25	July 26	May 8	May 28		
Alabama	June 7	June 28	Apr. 18	May 8	Apr 29	May 26
Mississippi			Apr. 18	May 8	Apr. 30	May 25
Louisiana						
Texas						
Oklahoma						
Arkansas						
Montana						
Wyoming						
Colorado						
New Mexico						
Arizona						
Utah						
Nevada						
Idaho						
Washington						
Oregon						
California						

TABLE XIV.—*Principal plants furnishing nectar and pollen; average dates of beginning and ending of blooming periods*—Continued.

State.	Shrubs—Contd.		Miscellaneous.[1]			
	Sumac (*Rhus*).		Raspberry (*Rubus strigosus* and other species).		Buckwheat.	
	Begin.	End.	Begin.	End.	Begin.	End.
Maine	....	....	June 10	July 5	July 20	Aug. 15
New Hampshire	....	....	....	....	Aug. 1	Sept. 1
Vermont	....	....	June 10	June 25	Aug. 1	Sept. 1
Massachusetts	July 8	Aug. 4	June 10	June 23	Aug. 1	Aug. 25
Rhode Island	July 6	Aug. 1	....	....	....	....
Connecticut	July 6	July 29	June 1	June 15	July 20	Aug. 10
New York	....	....	May 22	June 6	Aug. 4	Aug. 31
New Jersey	....	....	May 20	June 5	Aug. 1	Aug. 21
Pennsylvania	June 19	July 9	June 1	June 25	Aug. 4	Sept. 7
Delaware	....	....	....	....	Aug. 1	Aug. 25
Maryland	....	....	May 20	June 15	Aug. 5	Sept. 5
Virginia	June 10	June 20	....	....	Aug. 8	Sept. 8
West Virginia	June 10	July 5	May 15	June 5	Aug. 5	Sept. 1
North Carolina	....	....	....	....	Aug. 8	Spet. 10
South Carolina	....	....	....	....	....	....
Georgia	....	....	....	....	....	....
Florida	....	....	....	....	....	....
Ohio	....	....	....	....	Aug. 9	Sept. 10
Indiana	....	....	....	....	Aug. 2	Sept. 6
Illinois	....	....	....	....	....	....
Michigan	....	....	June 17	July 18	Aug. 9	Sept. 7
Wisconsin	....	....	June 1	June 26	July 29	Aug. 31
Minnesota	....	....	....	....	Aug. 1	Sept. 1
Iowa	....	....	....	....	Aug. 10	Sept. 5
Missouri	....	....	....	....	....	....
North Dakota	....	....	....	....	....	....
South Dakota	....	....	....	....	....	....
Nebraska	....	....	....	....	....	....
Kansas	July 1	July 31	....	....	....	....
Kentucky	....	....	....	....	Aug. 5	Sept. 1

[1] Cotton, principally July and August throughout the cotton belt. Horsemint (*Monarda*), Texas, May 10 to June 27. Pennyroyal (*Hedeoma*), Florida, November to February. Partridge pea (*Chamaecrista fasciculata*), Florida, July to September. Spanish needle (*Bidens, Coreopsis*), North Central States, late August to late September. Fire weed or willow herb (*Chamaenerion angustifolium*): Idaho, July 15 to Aug. 30; Michigan, July 15 to Sept. 15; Minnesota, Aug. 15 to Sept. 20; Oregon, July 1 to Oct. 1; Washington, July 1 to Aug. 30; Wisconsin, Aug. 15 to Sept. 20. Dandelion, during May in most Northern and Western States.

TABLE XIV.—*Principal plants furnishing nectar and pollen; average dates of beginning and ending of blooming periods*—Continued.

State.	Shrubs—Contd.		Miscellaneous.			
	Sumac (*Rhus*).		Raspberry (*Rubus strigosus* and other species).		Buckwheat.	
	Begin.	End.	Begin.	End.	Begin.	End.
Tennessee						
Alabama						
Mississippi						
Louisiana						
Texas						
Oklahoma						
Arkansas	June 20	July 5				
Montana						
Wyoming						
Colorado						
New Mexico						
Arizona						
Utah						
Nevada						
Idaho						
Washington						
Oregon						
California						

State.	Miscellaneous—Continued.			
	Fall flowers.[1]		Heartsease or heart-weed (*Polygonum persicaria*).	
	Begin.	End.	Begin.	End.
Maine	Aug. 20	Oct. 1		
New Hampshire				
Vermont				
Massachusetts	Aug. 27	Oct. 12		
Rhode Island				
Connecticut	Sept. 3	Sept. 28		
New York	Aug. 27	Sept. 28		
New Jersey	Sept. 1	Oct. 5		
Pennsylvania	Aug. 25	Oct. 4		
Delaware				

[1] Fall flowers, principally goldenrod and aster, former about a week earlier than latter.

TABLE XIV.—*Principal plants furnishing nectar and pollen; average dates of beginning and ending of blooming periods*—Continued.

State.	Miscellaneous—Continued.			
	Fall flowers.		Heartsease or heart-weed (*polygonum persicaria*).	
	Begin.	End.	Begin.	End.
Maryland	Sept. 1	Oct. 15		
Virginia	Sept. 1	Oct. 15		
West Virginia	Sept. 1	Oct. 15		
North Carolina	Sept. 20	Oct. 26		
South Carolina				
Georgia	Aug. 1	Oct. 15		
Florida	Aug. 1	Oct. 31		
Ohio	Aug. 22	Oct. 2	Aug. 1	Sept. 23
Indiana	Aug. 24	Sept. 23	Aug. 17	Sept. 19
Illinois	Aug. 15	Oct. 1	Aug. 10	Sept. 16
Michigan	Aug. 15	Oct. 23		
Wisconsin	Aug. 18	Oct. 23		
Minnesota				
Iowa			Aug. 10	Sept. 11
Missouri			Aug. 20	Sept. 30
North Dakota				
South Dakota			Aug. 1	Sept. 2
Nebraska	Aug. 10	Oct. 10	Aug. 1	Sept. 1
Kansas			Aug. 1	Sept. 15
Kentucky	Sept. 6	Oct. 12	Aug. 1	Oct. 1
Tennessee	Sept. 13	Oct. 17		
Alabama				
Mississippi				
Louisiana	Sept. 20	Nov. 1	Sept. 5	Nov. 1
Texas				
Oklahoma	Sept. 1	Oct. 15		
Arkansas	Sept. 15	Oct. 1		
Montana				
Wyoming				
Colorado	Aug. 1	Sept. 20		
New Mexico	Aug. 16	Oct. 6		
Arizona				
Utah				
Nevada				
Idaho	July 20	Aug. 30		
Washington				
Oregon				
California				

SOURCES OF POLLEN AND NECTAR.

The honeybee derives its supplies from the successive bloom of a great variety of trees, shrubs, and cultivated and wild plants and flowers, of which the family of the Leguminosæ is by far the most important. Many plants that are not sources of surplus honey are of great importance in the economy of the hives, furnishing the necessary supplies of pollen and nectar to enable the colony to increase the number of bees and thus build up its strength in the spring and to carry it through the winter or through periods of light honey flow during the summer. The average dates of bloom of the most important plants in the different States are shown in Table XIV. The dates given are only rough approximations, being merely the averages of the dates reported from the different States, and the bloom may be earlier or later in portions of particular States, especially those of large area or great diversity of climate.

TABLE XV.—*Sources of surplus honey.*

State.	Clovers.				Trees.						
	Alfalfa.	Alsike.	Sweet (*Melilotus*).	White.[1]	Fruit bloom.	Basswood.	Holly (*Ilex opaca*).	Black locust (*Robinia*).	Persimmon.	Sourwood (*Oxydendrum*).	Tulip poplar (*Liriodendron*).
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Maine		6.0	1.0	53.3	0.2	8.0		2.1			
New Hampshire				32.0	4.3						
Vermont				40.8		8.5					
Massachusetts		.5	2.1	25.5.	12.3	1.6					
Rhode Island				10.0							
Connecticut		1.2		20.3	4.4	3.5		1.2			
New York		1.6	2.1	30.2	.6	9.9		.2			
New Jersey		11.2	1.5	17.3				.8			1.5
Pennsylvania		2.1		13.1	.8	6.7					
Delaware				48.0	2.0	2.0		2.0			5.0
Maryland		3.1	1.9	26.0	.8	2.0		4.2			15.6
Virginia				26.7	1.2	3.0		3.4	1.4	12.2	7.8
West Virginia				26.8	1.1	10.7		.7		3.5	10.3
North Carolina				6.0	1.0	5.0	6.0	2.0	1.2	10.0	8.5
South Carolina				2.0			3.0	1.0	3.0	3.0	20.0

[1] Including red and crimson clover.

TABLE XV.—*Sources of surplus honey*—Continued.

State.	Clovers.				Trees.						
	Alfalfa.	Alsike.	Sweet (*Melilotus*).	White.	Fruit bloom.	Basswood.	Holly (*Ilex opaca*).	Black locust (*Robinia*).	Persimmon.	Sourwood (*Oxydendrum*).	Tulip poplar (*Liriodendron*).
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Georgia	......	......	......	2.0	1.0	......	3.0	......	1.0	3.0	16.5
Florida	......	......	......	......	......	......	......	......	......	......	......
Ohio	......	6.0	4.6	44.7	2.4	11.3	......	1.4	......	......	1.0
Indiana	......	2.9	5.2	37.3	......	3.0	......	.7	......	......	1.9
Illinois	......	2.2	10.6	37.0	.7	3.2	......	......	......	......	......
Michigan	......	6.9	.8	32.3	1.0	7.9	......	......	......	......	.6
Wisconsin	......	4.9	2.4	44.3	.2	9.0	......	......	......	......	......
Minnesota	1.9	2.8	4.4	38.6	.4	12.3	......	......	......	......	......
Iowa	......	2.2	7.4	57.9	.1	7.6	......	......	......	......	......
Missouri	......	.5	8.8	31.6	.3	.5	......	.1	......	......	......
North Dakota	......	......	......	......	......	......	......	......	......	......	......
South Dakota	13.5	1.5	37.3	27.7	......	......	......	......	......	......	......
Nebraska	21.7	2.2	18.9	18.6	......	2.7	......	......	......	......	......
Kansas	37.0	......	4.5	20.4	1.9	1.2	......	.7	......	......	......
Kentucky	......	......	12.8	26.8	2.0	5.0	......	5.9	2.0	......	3.0
Tennessee	......	1.2	......	39.3	......	6.0	......	5.0	3.0	13.0	8.8
Alabama	......	......	30.0	5.0	......	1.0	1.0	1.0	1.0	3.0	10.0
Mississippi	......	......	20.0	10.0	......	......	15.0	2.5	1.0	2.0	5.0
Louisiana	......	......	......	8.5	......	......	5.0	1.2	2.5	3.3	2.5
Texas	11.2	......	.7	......	......	......	1.7	......	.1	......	......
Oklahoma	35.0	......	25.0	.8	......	......	......	2.1	......	......	......
Arkansas	......	......	18.9	8.9	......	3.4	8.0	3.0	3.0	......	......
Montana	15.5	3.1	38.5	10.8	.2	......	......	......	......	......	......
Wyoming	36.4	......	35.0	......	......	......	......	......	......	......	......
Colorado	35.2	......	30.1	.8	......	......	......	......	......	......	......
New Mexico	62.2	......	19.3	......	......	......	......	......	......	......	......
Arizona	46.7	......	......	......	......	......	......	......	......	......	......
Utah	50.0	......	11.7	......	......	......	......	2.2	......	......	......
Nevada	67.5	......	5.0	......	......	......	......	......	......	......	......
Idaho	31.0	3.9	15.1	1.6	.5	......	......	......	......	......	......
Washington	20.0	......	13.0	2.0	3.3	......	......	.7	......	......	......
Oregon	25.0	11.0	5.0	7.0	7.0	......	......	......	......	......	......
California	29.0	......	2.2	......	......	......	.3	......	......	......	......
United States, average	7.7	1.4	6.2	19.6	.6	3.5	1.1	.9	.5	1.6	2.8

TABLE XV.—*Sources of surplus honey*—Continued.

State.	Trees—Continued.		Shrubs.			Berries.		Cultivated plants.		
	Tupelo and other gums (*Nyssa*).	Other.[1]	Gallberry (*Ilex glabra*).	Sumac (*Rhus*).	Other.[2]	Raspberry (*Rubus strigosus* and other species).	Other.	Buckwheat.	Cotton.	Other.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Maine						1.9		3.1		0.6
New Hampshire				0.7				3.5		
Vermont						7.2		4.6		
Massachusetts		4.5		.8		.5	2.6	9.0		
Rhode Island				25.0				5.0		
Connecticut		3.8		20.4		2.9	1.8	6.0		3.8
New York					0.2	2.1		24.2		
New Jersey						2.0	1.2	5.0		1.5
Pennsylvania						2.1		30.9		
Delaware				3.0		1.0		5.0		
Maryland				3.0			.8	2.5		
Virginia				4.1	.3	.3		2.0		
West Virginia		.7		4.3		.8		8.5		
North Carolina	18.0		20.0				5.0	1.5	2.0	
South Carolina	15.0		15.0				2.0		10.0	1.0
Georgia	17.5	1.0	13.2	1.0	5.0		1.5		10.0	2.0
Florida	35.0	40.2	.9		6.0				1.0	
Ohio						.1		1.7		
Indiana					.4			1.2		
Illinois								.3		
Michigan					.4	9.7		6.4		
Wisconsin						1.4		2.1		
Minnesota								1.2		.1
Iowa		.6			.1			1.1		
Missouri	1.7	.2		2.0						
North Dakota										
South Dakota					.3		1.5	.9		
Nebraska		.3						.3		
Kansas		.5						.2		1.4
Kentucky		1.5						.3		
Tennessee		1.9					1.0	.8		
Alabama	15.0		5.0		2.0		1.0		10.0	
Mississippi	10.8	5.0	2.0				6.2		7.0	5.0
Louisiana	15.7	6.3			15.5				6.3	15.0
Texas		5.0		2.2	25.3		1.0		24.5	9.7

[1] Including in Florida 5 per cent black mangrove (*Avicennia*), 15 per cent saw palmetto (*Serenoa*), 8 per cent cabbage palmetto (*Sabal*), and 10 per cent orange. California, 17 per cent orange.

[2] Including mesquite (*Prosopis*), 13 per cent in Texas, 13 per cent in New Mexico, and 43 per cent in Arizona; sage (*Ramona*), 22 per cent in California; catsclaw (*Acacia greggii*), 8 per cent in Texas, 1 per cent in New Mexico and Arizona; guajilla (*Havardia*), 4 per cent in Texas; wild buckwheat (*Eriogonum*), 11.2 per cent in California.

TABLE XV.—*Sources of surplus honey*—Continued.

State.	Trees—Continued.		Shrubs.			Berries.		Cultivated plants.		
	Tupelo and other gums (*Nyssa*).	Other.	Gallberry (*Ilex glabra*).	Sumac (*Rhus*).	Other.	Raspberry (*Rubus strigosus* and other species).	Other.	Buckwheat.	Cotton.	Other.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Oklahoma									15.0	
Arkansas	5.0	1.5			3.5			1.5	5.0	3.0
Montana					.5					
Wyoming										
Colorado										2.0
New Mexico		.4			3.8					
Arizona					43.8				2.9	
Utah										
Nevada										
Idaho					.7					
Washington		3.0								
Oregon		1.0			5.0					4.0
California		19.4			34.8				.7	1.5
United States average	3.1	3.8	1.6	.7	7.4	.6	.6	2.9	4.0	1.7

State.	Miscellaneous.					Blends.			
	Aster.	Goldenrod.	Heartsease or heartweed (*Polygonum persicaria*).	Spanish needle (*Bidens, Coreopsis*).	Other.[1]	Alfalfa and sweet clover.	Mixed clovers.[2]	Clover and basswood.	Other.[3]
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Maine	2.3	12.9			1.4		1.6	1.3	3.4
New Hampshire	5.9	13.6						21.0	19.0
Vermont		.3			4.5		11.7	16.3	6.1
Massachusetts		5.5			6.6			3.0	35.5
Rhode Island	5.0	15.0			10.0				30.0
Connecticut	8.0	17.3			5.4				
New York	.4	2.1	.4		.3		7.0	11.7	7.0
New Jersey	5.0	4.5	4.2		3.8		11.0	3.5	26.0
Pennsylvania	2.5	11.5		2.5			10.0	4.7	13.1
Delaware	4.0	10.0			5.0		5.0	3.0	5.0

[1] Including horsemint (*Mongardo*), 14 per cent in Texas; fireweed (*Chamaenerion angustifolium*), 1 per cent in Maine, 3 per cent in Minnesota, 22 per cent in Washington, 5 per cent in Oregon, trace in Michigan, Wisconsin, and Idaho; partridge pea (*Chamaecrista fasciculata*), 10 per cent in Georgia, 7 per cent in Florida; wild vetches, 15 per cent in South Carolina.

[2] Principally alsike and white clover, but mostly white and sweet clover in South Dakota, Nebraska, and Kansas.

[3] Including other blends with clover; 3 per cent in New York, 11 per cent in New Jersey, 3 per cent in Pennsylvania, 12 per cent in Maryland, 4 per cent in Virginia, and 20 per cent in North Carolina. Mostly aster and goldenrod.

TABLE XV.—*Sources of surplus honey*—Continued.

State.	Miscellaneous.					Blends.			
	Aster.	Goldenrod.	Heartsease or heart-weed (*Polygonum persicaria*).	Spanish needle (*Bidens, Coreopsis*).	Other.	Alfalfa and sweet clover.	Mixed clovers.	Clover and bass-wood.	Other.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Maryland	4.2	3.1			2.7		10.6	3.0	16.5
Virginia	3.0	1.4		0.7	3.7			3.0	25.8
West Virginia	3.3	2.1			6.5			12.7	8.0
North Carolina	2.7	1.0			2.3			2.0	6.3
South Carolina	1.5	1.5			20.0				2.0
Georgia	1.0	1.0			13.3				6.5
Florida		1.0			10.0				5.9
Ohio	1.2	1.1	0.4		.5		6.6	14.5	2.5
Indiana	6.1	3.4	7.0	.5	5.2		7.0	6.0	12.2
Illinois	2.0	3.7	17.1	7.7	2.7		1.0	5.7	6.1
Michigan	.6	2.9	.4		3.1		7.0	13.5	6.5
Wisconsin	.3	.7		.2	1.9		2.0	25.0	5.6
Minnesota	1.1	4.5	.2		7.5		6.7	16.0	2.3
Iowa	.2	2.6	7.0	4.6	3.4			3.5	1.7
Missouri	.3	2.4	7.5	13.7	4.5			10.0	15.9
North Dakota									
South Dakota		.6			4.4		12.3		
Nebraska	1.4	5.2	11.2	.3	3.1		9.0		5.1
Kansas		1.8	8.3		12.6		5.0		4.5
Kentucky	10.0	5.8	2.3		11.6		3.0		4.0
Tennessee	6.7	1.5			10.3				1.5
Alabama	1.0			1.0	8.0				5.0
Mississippi					7.5				1.0
Louisiana		2.0	2.0		5.0				19.2
Texas					18.6				
Oklahoma			5.2	4.2	12.7				
Arkansas		6.2	2.0	3.5	9.6				14.0
Montana	.3	.3			3.1	27.0			.7
Wyoming						28.6			
Colorado		.8			1.1	30.0			
New Mexico		2.7			9.1				2.5
Arizona					2.0				4.6
Utah					2.8	25.0			8.3
Nevada					2.5	25.0			
Idaho		.6			.2	43.0			3.4
Washington		1.7			26.3	10.0			20.0
Oregon					21.0	12.0	2.0		
California					9.1				3.0
United States, average	1.4	2.1	2.0	1.3	7.6	1.4	2.0	4.0	5.9

NECTAR SOURCES FOR SURPLUS HONEY.

The principal sources of surplus honey, that is, honey which is removed from the hive by the beekeeper for his own disposition, in contradistinction to that consumed by the bees, are shown in Table XV.

It is to be observed that the clovers, including alfalfa and sweet clover, belonging to the great family of the Leguminosæ, are the most important source of the country's honey, these alone furnishing 34.9 per cent of the entire supply, besides the larger component (probably 8 per cent) of the 13.3 per cent additional of blended, or mixed honey. Of the clovers, the most important is the small, low growing white clover of the lawns and fields, credited with 19.6 per cent of the total supply. Next in importance is alfalfa, furnishing 7.7 per cent, and its near relative, sweet clover, furnishing 6.2 per cent. Alsike, 1.4 per cent, has probably been reported in some cases as white clover, blooming at the same time and producing the same type of honey. Red clover is mentioned occasionally, as in dry seasons when the corolla tubes are short enough for the bees to reach the nectar, its profuse secretion is utilized. This and crimson clover, a source of nectar in a few southeastern States, are included under white clover, as are all reports of clover simply, without further designation, as the honey from all these excepting sweet clover and alfalfa, is almost identical, and in common practice is handled as white clover honey.

Among the trees, the heaviest producer is the basswood, credited with 3.5 per cent pure, and with white clover as a blend amounting to 4.0 per cent additional. The tulip poplar furnishes 2.8 per cent, and the sourwood 1.6 per cent, the last, however, often being given credit for honey actually derived from other sources. The tupelo and other gums, 3.1 per cent, and the holly, 1.1 per cent, are bountiful producers in limited Southern areas. For heavy yields the orange and other citrus trees are notable, and orange honey, 2 per cent, is of importance commercially. No other tree is credited with as much as 1 per cent of the total, although in many sections black locust is important in an occasional season. Among tree shrubs and bushes, the mountain sages, 2.3 per cent, the mesquite, 2 per cent, wild buckwheat, 1.1 per cent, and catsclaw, 0.8 per cent, are extremely important in the regions of their growth. These are all plants of the semiarid regions. Gallberry, a type of shrub holly, furnishes 1.6 per cent, and sumac 0.7 per cent. Of berries, the wild raspberry is locally important, blackberry and huckleberry being less so.

Of cultivated plants, cotton is most important, furnishing 4.0 per cent of the total supply. Buckwheat is a heavy producer. It contributes 2.9 per cent.

Of the weeds, goldenrod heads the list, producing 2.1 per cent, its growth being very widespread. Heartsease or heartweed, 2 per cent, and Spanish needle, 1.3 per cent, are important in the Central West, and wild aster, 1.4 per cent, has a very wide distribution.

GEOGRAPHICAL DISTRIBUTION AND CHARACTERISTICS OF IMPORTANT HONEYS.

HONEYS OF THE WHITE CLOVER BELT.

The white clover belt, marking the principal range of the wild growth of this lowly but beneficent plant, wherein it invades the grasslands, yielding nitrogen to the soil, food to the grazing stock, nectar to the bee, and beauty to the eye, includes all of the States from Maine southward to Virginia and the Allegheny and Piedmont sections of the southestern States, and all of the territory westward to the beginning of the semiarid plains beyond the one hundredth meridian of west longitude. White clover is also becoming important in some western irrigated sections and in the limestone and alluvial soils of Alabama, Mississippi, and Louisiana. The white clover belt is the most important honey-producing region, because it furnishes not only the leading commercial type, but all told more than half of the total honey crop of the entire country. The limpid whiteness, heavy body, and distinct but delicate and delicious flavor of white clover, worthy of the dainty clustered blossom whose aroma it bears, long ago established it as a standard of excellence. It should not be asserted that this is the best honey, but if it is said of a honey that it is "as good as white clover," it is considered sufficient praise.

The basswood (linden, Linn.) tree, found native in our forests and planted extensively as an ornamental and shade tree, which furnishes a honey of fine quality when well ripened, and of superlative quality in its frequent blend with white clover, grows in much the same region as the latter, except that it does not extend so far to the southward, being found native south of the latitude of Pennsylvania only as a rule at the higher levels and as far south as North Carolina only in the northern coves of the mountains.

Other principal types of honey produced in the white clover belt are, in relative order of total production, as follows:

Buckwheat, a dark honey of rather strong flavor, much esteemed by those familiar with it, but having practically no market as a table honey outside of the buckwheat-growing sections of New York and other Northern States and the Appalachian region.

Goldenrod, from a very widespread plant, a highly flavored honey with a beautiful golden color, rated as one of the finest of fall honeys, but too rich for many who prefer delicate flavors.

Heartsease honey, from the weed, not the violet, of that name, important in the central corn States, and to a lesser extent in the States east. When produced pure, it is a white or light amber honey of handsome appearance, but of a flavor that wins it no favor outside of the area of its production. Where a constituent of mixed honeys and in not too great proportion it is not objectionable, but rather pleasing.

Aster, the almost universal fall honey, obtained from the common roadside wild aster, a strong amber or dark honey rarely used except for cooking.

Spanish needle, a light golden honey with a distinctive flavor, a very good type and considered superior by many, obtained in considerable quantities during late August and throughout September from the heavy growth of this weed in swamps and along the water courses, in much the same territory as heartsease.

Black locust, a very good light honey from the familiar leguminous tree so favorably known as the source of durable fence posts, which, during the month of May and often too early for bees to obtain full benefit of its bounty, stands a great cluster of fragrant, snowy bloom for from 10 days to a fortnight, said to yield when weather conditions are favorable, though usually only at intervals of several years, a large amount of honey.

Sumac, broadly distributed, an amber or dark product, with a strong and fruity flavor which is tempting to many.

Apple, and other tree fruit bloom, light amber honey of a very fine flavor when well ripened by the bees.

Raspberry, a white and extremely finely flavored honey produced in considerable quantities in northern Michigan, and less freely elsewhere along the northern border, from the wild raspberry, which covers large areas of cut-over timberlands.

Milkweed, highly esteemed and produced in considerable quantities in limited localities in Michigan and other States where this well-known wayside plant grows in abundance.

Blueberry and huckleberry, a dark honey carrying the flavor of the fruit and greatly prized in the favored localities where obtainable.

WESTERN HONEYS.

Alfalfa, the second most important source of honey, known of ancient days as the "best fodder" and rapidly gaining in this country the respect and place due its worth, yields nectar freely in the region of its principal growth, beyond one hundredth meridian of west longitude and throughout the western Mountain and Pacific Coast States. It is occasionally reported as yielding nectar in some eastern sections. This is usually a white honey except in the southwestern tier of States, where it darkens to amber, with a distinctive spicy or minty flavor, but with a tendency to granulate (crystallize and become semisolid). Owing to its high quality and extremely heavy production throughout the western irrigated regions, it is an important honey commercially.

Sweet clover, a native legume and a very close relative of alfalfa, which in the early stages of growth it resembles closely, is of next importance, the honey being similar in appearance, but of a superior flavor, and with a lesser tendency to granulate. The plant grows wild in dense masses throughout all of the western Mountain and Plateau States and the central and northern plains, along irrigation ditches and in waste lands, wherever moisture is sufficient. It is also common in all of the Central States eastward to the Atlantic coast, bordering the steam and wagon roads, and is an important honey plant in many sections there and in the black lands of Alabama and Mississippi, especially where cultivated as a forage plant.

The mountain sages of California produce a type of honey of much importance commercially and by common consent one of the finest of all in color (white), density, and flavor. The sage honeys possess, in addition to other virtues, the important one of not granulating readily. Honeys from the desert plants other than sage are as a rule good; many are excellent and rarely are they of poor quality.

Orange honey ranks high among the commercial honeys, being produced in large quantities in California, and to a less extent in Florida, Arizona, and a few of the Gulf Coast States. When produced under favorable atmospheric conditions, as a rule, it is of fine appearance, body, and flavor, and is ranked as one of the very best.

Other sources of favored western honeys are few, but among them fireweed, which follows fires on cut-over lands in western Washington and Oregon, as well as in the northern fringe of the Eastern States, is unexcelled. Vine maple is important in Oregon.

California, the leading honey State, owes its preeminence to four principal sources of supply—the alfalfa of the valley sections, the wild sage and the wild buckwheat shrub of the southern hills and mountains, and the citrus groves.

Of the Texas crop, second in importance, roughly two-fifths is produced in south Texas from the wild horsemint and from the mesquite, catsclaw, guajilla, and other desert trees and shrubs, a scant fifth in the western section of the State beyond the Pecos River from alfalfa and desert plants, and most of the remaining two-fifths in the black waxy soil belt and the prairies of central Texas, principally from cotton, though a considerable quantity is from horsemint and some from mesquite. Rattan, huckleberry, and holly supplement cotton and horsemint in the eastern part of the State.

SOUTHEASTERN HONEYS.

Tupelo gum honey is produced in large quantities from the tree of that name in the regions adjoining the east Gulf coast, principally in swampy sections and along the rivers, and while a honey of good flavor and fair color is in demand mainly because of its nongranulating properties for mixing with other honey. Other gum trees also are sources of honey, but, as a rule, the quality is inferior, and yields are not so heavy.

Cotton honey is white and of fair flavor. It is produced freely in portions of the cotton region, particularly in Texas, though in some sections the plant yields little or no secretion, which, incidentally, is extra floral, the sweet secretion appearing on the stem bracts below the flower and upon the under surface of the leaves.

The tulip poplar tree, growing freely throughout the eastern and southeastern United States, often to an immense size, furnishes an abundance of nectar early in the season, often before the colonies of bees are sufficiently built up to take full advantage of it. The honey is of reddish amber tint and of inferior though not unpleasant flavor and is rarely handled commercially except for cooking purposes.

The Southern States produce several honeys of superior flavor which are consumed on the local market and rarely reach general commercial channels. Among these may be mentioned the sourwood of the Southern Appalachians, the gallberry of the South Atlantic and East Gulf coasts, the saw palmetto and mangrove of Florida, holly, persimmon, partridge pea, and titi. (Cliftonia.)

PRODUCTION OF 1917.

The yield of honey for the year just passed has been only fair, 40.3 pounds average, being much below last year's figure of 52.8 pounds, and slightly below the 42.3 pounds of 1915. The coolness of the season in most of the Central and Eastern States, with local droughts, and prior winterkilling of clover over considerable areas, coupled with periods of extreme heat in the Far West, were principally responsible for the relatively disappointing crops realized in 1917 in spite of earnest efforts on the part of beekeepers toward heavy production.

CONDITIONS AND PROSPECTS FOR 1918.

The increase in number of colonies during the season over and above losses is 11.5 per cent, which will allow for an average winter loss without a material reduction of numbers below that of 1917. The condition of colonies at the beginning of winter was reported as 93.2 of normal, only slightly below the high condition of 95.5 in 1916, and in only four States did it fall below 90, although one of these is the important honey-producing State of Texas, where extreme and long-continued conditions of drought reduced the condition to 81.

The supply of honey in the hives on November 1 was generally ample for ordinary winter requirements, but the severe winter in the central and eastern States threatens heavy losses and weak condition of a large proportion of the surviving colonies in the spring of 1918.

The character of the season controls the yield in a broad sense, but a material increase in production of honey over what may otherwise be expected might be realized if beekeepers generally could be aroused to the importance of the subject and would make special effort by giving attention to the bees in the fall and early spring to see that their stores are ample, by feeding if any shortage exists, by protecting them so far as possible from the inclement winds and freezing temperatures of winter and early spring, by supplying ample room in the brood chamber for the expanding brood (not so early, however, as to lead to harm from undue exposure), by giving plenty of space at the proper time for storing surplus, and by the production of extracted honey. This last expedient, besides permitting a marked increase in production by most beekeepers and in most seasons over that of comb honey, by lessening the amount of comb building and avoiding heavy swarming during the season of surplus production, also involves much less labor in caring for the bees.

The May 1, 1918, report, received just as this bulletin goes to press, shows that the losses of colonies of bees during the past winter have been, for the United States as a whole, 18.7 per cent of the total number; in other words, almost one out of every five colonies has perished. As the reports to the bureau are in the main from the better class of beekeepers it is to be feared that the wastage has been even greater. Under the present circumstances, this loss assumes an aspect tragic not only to the multitude, almost a million, of industrious and interesting insect communities whose ardent haste and joyous hum have been stilled, but to their human erstwhile beneficiaries. The Nation can ill spare the 20 to 30 million pounds of honey which past experience permits us to assume as the potential production of these lost colonies. Roughly, a third of these losses are ascribed to freezing and another third to starvation, and it is sad to reflect that both of these causes might in large measure have been overcome by their proprietors and protectors. Sugar and labor shortage are partial, but only partial, excuse, as is the unusual winter, which came early, shortening the flow of nectar from the autumn flowers, and persisted with unexampled severity without the customary brief relaxations which in ordinary years permit of late cleansing flights by the hive-bound bees before the settled cold of midwinter.

Lost or failing queens and small colonies resulting from brood diseases or late swarming are as usual the principal other reported causes of loss.

The losses were most severe in the North Central and Northeastern States and extending as far southward as North Carolina, Tennessee, Missouri, and Kansas, ranging in some States as high as 41 per cent and in only a few cases falling below 15 per cent. The losses in the South and West have been less than usual, with the exception of Oklahoma and California, and notably Texas, in which State drought of two-year duration in important honey-producing sections created conditions that resulted last winter in 24 per cent of loss. This drought was happily ended by copious rains early in May.

The number of working colonies remaining on May 1 is estimated at 88.7 per cent of the number on May 1, 1917. Material increases last year partly offset the heavy losses. Increases are shown over last year's numbers in most of the Southern and Western States.

The condition of colonies is 86.4 per cent of a normal at this date, compared with 91.1 per cent last year and an average of 94.2 per cent, reflecting the bad effect upon the surviving colonies of the severe winter. The colonies appear to be building up rapidly, however. Colonies are reported in excellent condition in most Southern States, excepting Texas, and are above normal in several of the western group, although in California they are in only a trifle better than last year's poor condition, and still 10 per cent below the average.

The condition of honey plants is reported at 86.7 per cent, which is considerably better than the 82.3 per cent reported last spring, but distinctly below the average of 92.6 per cent. The lowest conditions are in Wisconsin, Iowa, and South Dakota, owing to winter killing of clover, and in Texas and Oklahoma, resulting from droughts.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 686

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

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FURTHER STUDIES OF THE ROTS OF STRAWBERRY FRUITS.

By NEIL E. STEVENS, *Pathologist*, and R. B. WILCOX, *Scientific Assistant, Fruit-Disease Investigations.*

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INTRODUCTION.

The results of the investigations of the rots of strawberry fruits (*Fragaria* sp.) made by the writers during the two years ended in the spring of 1917 have already been published (10 to 12).[1] Since the preparation of these papers the problem has been studied somewhat more extensively. The work for the season of 1917 included field investigations in Florida, Alabama, and Louisiana, with experimental shipments between Hammond, La., and Chicago during April, and field work in Missouri and in the region about Norfolk, Va., in May. Observations were also made of the fruit in the various markets, most of the important markets east of Minneapolis being visited at least once during the season.

Through the courtesy of H. J. Ramsey and V. W. Ridley, of the Office of Handling and Storage Investigations of Fruits and Vegetables, one of the writers was able to accompany car-lot shipments of strawberries from Monett, Mo., to St. Paul, Minn., in order to study the condition of these shipments and to include inoculated fruit in the cars.

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[1] The serial numbers in parentheses refer to "Literature cited," at the end of this bulletin.

RHIZOPUS.

TYPE OF ROT INDUCED.

Among the numerous fungi which have been found growing on ripe strawberries, Rhizopus, as pointed out in an earlier paper (12, p. 4), is by far the most important. This fungus destroys strawberry tissue more rapidly than any other yet found and causes the affected fruits to collapse with the loss of much juice, producing the characteristic "leak" which so frequently discolors strawberry boxes and crates in the market. The spores of this fungus are apparently very generally present on ripe strawberry fruits.

A list of fruits and vegetables on which *Rhizopus nigricans* Ehrb. has been reported was published by the writers (12, p. 9). On June 1, 1917, this fungus was observed fruiting abundantly on red raspberries (*Rubus* sp.) and dewberries (*Rubus* sp.) in the Chicago market, and later (July 23) on blackberries in the Washington market. In all these cases the fungus seemed to be producing the leak characteristic of its action on strawberries and other fruits (12, p. 11). The berries had settled to about one-half their original height in the box, and the juice was leaking from the bottoms of the boxes or crates.

It is of interest to note that in his studies of Rhizopus, Wormald (14, p. 483) proved that both the so-called plus (+) and minus (−) strains of this fungus are able to produce the characteristic soft rot of tomatoes (*Lycopersicon esculentum*).

It is probable that Rhizopus occurs as a fruit rot of tomatoes in this country, although no reference to it can be found in available literature. In a car of tomatoes from Cuba which was examined in Boston in January, 1918, by Mr. C. E. Merrill, food products inspector of the Bureau of Markets, and one of the writers, several instances were found in which a species of Rhizopus was producing a soft rot of tomatoes.

IMPORTANCE OF CAREFUL HANDLING.

Early in their investigations (10, p. 364) the writers became convinced that Rhizopus rarely, if ever, enters strawberries through th uninjured epidermis. Continued observations and experiments hav confirmed this conclusion. As strawberries are very easily injur they should be handled as little and as carefully as possible. S ing, or at least some examination at the packing shed, is usually n sary, but berries should be handled carefully in order to reduc minimum injury and the consequent decay. When practica when most of the picking is done by the grower's family or perienced help, the berries may be sorted as picked. This is p the most desirable procedure. The importance of careful as a means of reducing loss from decay in various fruits clearly shown in several investigations by Ramsey (5 and ell

(4), and others, and it is apparently of first importance in the strawberry.[1]

IMPORTANCE OF LOW TEMPERATURE.

The careful studies of Miss Ames (1) indicate the close relation between temperature and the rate of growth of Rhizopus. Rhizopus grows very slowly at a temperature of 10° C. (50° F.). The rate of growth increases very rapidly with the rise of temperature above that point, however, so that the fungus will develop more in a short time at a relatively high temperature than in a much longer time at a lower temperature. Miss Ames found, for instance, that *Rhizopus nigricans* would produce mature sporangia in 36 hours at a temperature of 33° C., while at temperatures of 10° to 12° C. three weeks were required.

The importance of low temperature in reducing rots of strawberries was strikingly shown by tests conducted in connection with experimental shipments between Monett, Mo., and St. Paul, Minn. Similar boxes of strawberries of the Warfield variety were inoculated with spores and mycelium of *Rhizopus nigricans* through needle wounds. The berries, at a uniform temperature of about 24° C. (75° F.), were all placed in the cars about 6 p. m.

Accurate temperature records kept by Mr. V. W. Ridley showed that the most marked difference in the conditions to which the four boxes referred to in Table I were subjected was in the time consumed in reaching a temperature below 10° C. (50° F.). Examination of the fruit four days later, on arrival at destination, showed that the longer the time consumed in reaching 10° C., the greater the amount of rot developed. The results are summarized in Table I.[2]

TABLE I.—*Relation of temperature to the growth of Rhizopus in inoculated strawberries of the Warfield variety, in connection with experimental shipments between Monett, Mo., and St. Paul, Minn.*

Crate.	Hours consumed in reaching 10° C. (50° F.).	Condition on examination after arrival at destination.
No. A......	40	Berries practically all rotten, most of them bearing aerial hyphæ with immature sporangia.
No. B......	30	All berries showing a rotten area about one-fourth of an inch in diameter around the inoculation.
No. C......	7	70 per cent of berries showing no indication of fungous growth, the remaining 30 per cent showing small rotten spots.
No. D......	5	91 per cent of berries showing no indication of fungous growth, the remaining 9 per cent showing very slight softening around the point of inoculation.

Other boxes of inoculated fruit of the Warfield variety, as well as some Aromas, were also included in this experiment. The results in all cases were similar to those given in Table I. The significant fact is that the only perceptible difference between the boxes was in their temperature after loading on the cars. Boxes of berries as nearly alike as possible were chosen for the experiment. The berries were of the same variety, grown in the same locality, picked at the same time, and inoculated in the same way with the spores and mycelium of *Rhizopus nigricans* which came from a single original culture.

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[1] Mr. E. L. Markell, of the Bureau of Markets, informs the writers that his own investigations, conducted during 1915 and 1916 at Hammond, La., the results of which are as yet unpublished, clearly showed the importance of care in handling strawberries.

[2] See also Ridley, V. W. Factors in transportation of strawberries from the Ozark region. U. S. Dept. Agr., Markets Doc. 8, 10 pp., 6 fig. 1918.

WASHING STRAWBERRIES.

Washing strawberries before packing for shipment is regularly practiced by a few growers in Florida and is resorted to by a large number when the berries are very sandy. Experiments conducted in Florida by the writers during 1916 (12, pp. 15–19) showed that the practice is not necessarily harmful provided the fruit is packed wet,[1] handled with care, and placed under refrigeration within a reasonable time. They indicated, indeed, that the keeping quality of the fruit might even be improved by this treatment. To allow the washed fruit to dry before packing, on the other hand, had a decidedly injurious effect.

In order to verify these results, the writers experimented by washing strawberries in Louisiana and Missouri during 1917. Various methods of washing were first tested. Experiments were conducted in which a part of the berries were packed in boxes and then washed either by dipping the entire box in clean cold water or by running the water over and through the box, while an equal quantity of the berries was poured into the water, dipped out immediately, and then packed in boxes. Klondike berries picked at Hammond, La., were used and after treatment were placed in crates while wet and examined after 48 hours. Table II summarizes the results of these tests.

TABLE II.—*A comparison of the keeping quality of strawberries washed before packing with strawberries washed after packing at Hammond, La., in 1917.*

Treatment.	Washed after packing.		Washed before packing	
	Number of berries.	Sound on examination.	Number of berries.	Sound on examination.
		Per cent.		*Per cent.*
Held without refrigeration	183	28	143	13
Shipped to Chicago under refrigeration	820	56	786	45
Total	1,003	51	929	40

Without exception, the results were in favor of packing the fruit before rather than after washing. In subsequent washing experiments, therefore, this method was followed.

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[1] Still better results are obtained by packing dry and then washing.

In six tests, which included three varieties from two localities, washed berries which had been placed in the crates while wet were compared with unwashed berries. The results are given in Table III.

TABLE III.—*Effect of washing strawberries, as shown by six tests of fruit grown in Louisiana and Missouri in 1917.*

Test.	Variety.	Locality where grown.	Unwashed fruit.		Washed fruit.	
			Number of berries.	Sound.	Number of berries.	Sound.
				Per cent.		*Per cent.*
No. 1	Klondike	Hammond, La.	268	41	243	26
No. 2	Russell[1]	do	222	40	228	26
No. 3	Klondike	do	234	42	194	43
No. 4	do	do	638	49	658	52
No. 5	do	do	192	58	162	72
No. 6	Warfield	Monett, Mo	230	57	198	81

[1] A local name.

As was stated in a previous paper (12, p. 18), the improvement in the keeping quality due to washing berries is greatest when the temperature of the air is highest, as the improvement is apparently due to the fact that the wetted berries are at a lower temperature during the interval between packing and placing under refrigeration. The results given in Table III emphasize these facts. In tests Nos. 1 and 2 the berries were picked between 8 and 9:30 a. m. on a bright but rather cool morning following a heavy rain. Many of the berries were still wet, and their temperature was not materially lowered either by dipping or subsequent increased evaporation. The chief effect of the treatment was, then, the slight bruising incident to dipping, and the results are unfavorable to the washed fruit.

In tests Nos. 3 to 6, however, the berries were picked between 11 a. m. and 3 p. m. on warm bright days when the immersion and evaporation actually lowered the temperature of the washed fruit considerably below that of the dry.

In tests Nos. 1 to 4 the berries were kept without refrigeration for 24 hours before being loaded into cars for shipment to Chicago. The cooling due to washing persisted for only a few hours, after which the berries reached a temperature favorable for fungous growth and remained at that temperature for a considerable time prior to being placed in refrigerator cars, so the beneficial effect due to washing was largely lost. In the last two tests, on the other hand, the berries were loaded into iced cars within a few hours after picking and washing, so that the cooling effect persisted for the entire interval and the berries did not reach air temperature at any time. Under these conditions washing markedly improved their keeping quality.

The experiments in 1916 showed that if washed berries are allowed to dry before being packed their shipping quality is injured. To obtain further data on this point three shipments of Klondikes from Hammond, La., to Chicago, Ill., were made in April, 1917. The results, which are summarized in Table IV, agree closely with those of the previous year.

TABLE IV.—*Effect of drying washed strawberries before packing, as shown by shipments of fruit from Hammond, La., to Chicago, Ill.*

Treatment.	Number of berries.	Sound on examination.
		Per cent.
Not washed	1,064	49
Washed and packed wet	1,014	53
Washed, dried in shade, and packed	1,037	37

As already stated, by this treatment the beneficial cooling effect of continued evaporation from the berries is lost, and the harmful effects of softening and extra handling are emphasized.

Smith and Goodman (13, p. 84; see also 12, p. 17) found that strawberries dried for an hour in a strong current of air from an electric fan carried to market in better condition than those even slightly wet. In order to review the conclusions of these investigators, two tests were made at Hammond, La., in which wet berries were fanned before being packed. In one test the berries were prepared and held for 24 hours at room temperature, after which they were shipped to Chicago under refrigeration. In the second case they were placed in an iced car for shipment as soon as they were prepared. The results are shown in Table V.

TABLE V.—*Effect of fanning strawberries before shipment, as shown by two tests of fruit grown at Hammond, La., and shipped to Chicago, Ill.*

Treatment.	Held 24 hours without refrigeration before shipment.		Packed and shipped immediately.	
	Number of berries.	Sound on arrival.	Number of berries.	Sound on arrival.
		Per cent.		*Per cent.*
Not washed or treated	234	42	192	58
Not washed, but fanned 1 hour	....	....	184	54
Washed and dried in shade 1 hour	234	23	165	54
Washed and packed wet	194	43	162	72
Washed and fanned 1 hour	164	23	186	70

These results and those of other tests (see Table IV; also 12, pp. 16–19) indicate that no injury is likely to follow shipping berries wet. As the writers' work was done in Louisiana and Smith and Goodman's in Canada, no very satisfactory basis for a comparison of results is presented.

TEMPERATURE AT TIME OF PICKING IN RELATION TO DECAY.

Another striking illustration of the importance of temperature in controlling Rhizopus rot is found in the relation of the rate of decay to the temperature at the time of picking. In studies which are to be reported in detail elsewhere, the writiers have determined that on clear days the temperature of many small fruits, including strawberries, is much higher near midday than in the early morning or late afternoon. Experiments have shown further that the decay of strawberries picked near noon is more rapid than that of similar berries picked early in the morning. For example, strawberries of the Klondike variety were picked at Hammond, La., at various times and held in the packing shed until about 4.30 p. m., when they were shipped to Chicago under refrigeration in the regular express service, which gives second-morning delivery. They were examined and sorted on the day following their arrival. (Series A, Table VI.) Wider differences in keeping quality were obtained with another series picked and shipped under similar conditions. (Series B, Table VI.)

TABLE VI.—*Keeping quality of strawberries in relation to temperature at time of picking, as shown by three series of tests of fruit grown at Hammond, La.*

Time of picking.	Temperature when picked.		Number of berries.	Sound on examination.
	° *C.*	° *F.*		*Per cent.*
Series A:				
8 a. m.	24.5	76	140	52
9.15 a. m.	28.5	83	142	56
10 a. m.	31.0	88	204	52
12 m.	32.0	90	90	40
2 p. m.	30.5	87	133	55
4 p. m. (cloudy)	26.0	79	180	57
Series B:				
6 a. m.	15.0	59	165	65
8 a. m.	23.5	74	103	58
10 a. m.	29.5	85	273	50
12 m. (drifting clouds)	31.0	88	109	29
2 p. m.	35.0	95	153	30
4 p. m.	32.5	91	115	30
Series C:				
12 m.	31.0	88	162	12
2 p. m.	35.0	95	248	11
4 p. m.	32.5	91	222	20
5 p. m.	30.0	86	270	22
6.45 p. m.	21.0	70	387	34

In order to ship the berries to Chicago under refrigeration, it was necessary to discontinue each test at 4 p. m. (series A and B, Table VI). A third series of tests was accordingly made on the same day as that of series B, in which the berries were held at air temperature at Hammond, La., for two days, with the results shown. (Series C, Table VI.)

The results of the tests designated as series C, which parallels that recorded under Series B, Table VI (from 12 m. until 4 p. m.), indicate that berries picked late in the afternoon, after their temperature had fallen, kept better than those picked during the hottest part of the day.

BOTRYTIS.

RELATION OF BOTRYTIS INFECTION TO MOISTURE CONDITIONS.

Botrytis [1] is characteristically a cause of field rot of strawberries. It is, however, by no means of uniform importance. Its abundance seems to be closely correlated with moisture conditions. During the past three years the writers have observed three epidemics of Botrytis, all associated with abundant moisture. The first occurred in the early part of June, 1915, at the Arlington Experiment Farm, in Virginia. Not only were green and ripe fruits affected, but fruit pedicels and leaf petioles as well.

The epidemic began during a week of almost continuous cloudy weather in which over 3 inches of rain fell, as indicated by the accompanying report (Table VII) taken from the Monthly Meteorological Summary for Washington, D. C., published by the Weather Bureau of the United States Department of Agriculture.

TABLE VII.—*Meteorological data, Washington, D. C., May 28 to June 3, 1915.*

Date.	Temperature (° F.).		Precipitation (inches).	Character of day.	Percentage of possible sunshine.
	Maximum.	Minimum.			
May 28	76	48		Partly cloudy	37
May 29	61	57	0.12	Cloudy	0
May 30	57	52	.10	do	0
May 31	73	52		Clear[a]	90
June 1	68	49	.11	Cloudy	26
June 2	64	54	3.00	do	0
June 3	59	49	.03	do	1

[a] Corrected from the published Monthly Meteorological Summary on the advice of Mr. M. C. Bennett, acting chief, Climatological Division, Weather Bureau.

This infection occurred on the experimental plats of the Office of Horticultural and Pomological Investigations, in which a test was being made of more than 300 varieties of strawberries. No difference in the susceptibility of the different varieties could be noted.

A strongly localized epidemic which was of special interest because of its evident direct relation to moisture conditions occurred at Hammond, La., following a rain on April 16, 1917. On one field known for its high yields and careful culture there was great loss from Botrytis. The loss was markedly greater on one side of the field where a grove of tall trees shaded the plants during the early part of the day and evaporation took place more slowly than elsewhere. More than half of the berries picked in this field on one day were discarded as culls because of Botrytis infection. The inspection of fruit by many growers was unfortunately less rigid, however, and during a few days some shipments contained large numbers of such culls.

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[1] While careful comparative studies of material from various localities have not been made, the collections of Botrytis on strawberry fruits appear to belong to a single species, probably *B. cinerea* Pers.

In a field of the Russell variety in the same locality the moisture relation was still more evident. The soil was heavy and rather impervious, and in about 20 rows which had been coarsely cultivated just before the rain the ground was left rough and uneven. Following the rain, the water stood in pools under and around the plants in these rows after the smoothly packed uncultivated part of the field was drained and fairly dry. On the morning of April 18 a large proportion of the mature and green berries in the rough ground were infected with Botrytis, while only a small percentage of those in the rows on either side were diseased.

The third and very interesting, though less marked, epidemic occurred at Monett, Mo., during May, 1917. The first examination of the fields in this vicinity was made Sunday, May 20, following a period of drought which threatened the strawberry crop. At that time no evidence of Botrytis could be found. During the following week there was some rainfall nearly every day and comparatively little clear weather, as is shown by the accompanying report of weather observations at the near-by station of Springfield, Mo., kindly furnished by Mr. W. B. Hare, observer at that station (Table VIII). Throughout the week, May 20 to 26, strawberries in that vicinity were constantly under observation, and there was a more or less regular increase in the amount of Botrytis on the fruits, until in fruit picked Saturday, May 26, as many as 10 per cent of the berries in some fields were found to be affected by Botrytis.

TABLE VIII.—*Meteorological data, Springfield, Mo., May 20 to 27, 1917.*

Date.	Temperature (° F.).		Precipitation (inches).	Character of day.	Percentage of possible sunshine.
	Maximum.	Minimum.			
May 20	72	61	0.45	Partly cloudy	28
May 21	68	58	.69	Cloudy	20
May 22	62	41	.02	do	0
May 23	62	40	.02	Clear	87
May 24	68	51	.07	Partly cloudy	44
May 25	66	57	.54	Cloudy	6
May 26	80	66	0	Clear	67
May 27	67	53	.74	Cloudy	7

GROWTH OF BOTRYTIS ON STRAWBERRIES UNDER REFRIGERATION.

As a cause of rot in transit Botrytis is of minor importance. Its development on ripe strawberries is so slow that it seldom does much damage in transit. Its presence in boxes is usually due to improper sorting. Most berries attacked by Botrytis can be detected and should be removed when the berries are packed. The importance which has been attributed to Botrytis (7, p. 950) is apparently largely due to its frequent occurrence in strawberry fields under certain circumstances and to its ability to produce aerial hyphæ at relatively low temperatures. Under the conditions found in many refrigerator cars, strawberries affected with Botrytis often develop abundant fine, gray, sterile aerial hyphæ, often 2 cm. or more in length. A few such berries on the top of a crate attract immediate attention and give the impression of general decay. On removal from the cool, moist air of the refrigerator car these aerial hyphæ collapse and are replaced by much shorter (2 to 3 mm.) fertile hyphæ, which produce mature spores in a short time, often within 36 hours.

The ability of Botrytis to grow at low temperatures has been frequently noted. Brooks and Cooley (2, pp. 156 and 159, fig. 15) found that it would grow somewhat at 0° C. on corn-meal agar in Petri dishes and would even germinate at this temperature, while Fulton in the course of storage experiments on small fruits found that this fungus (3, p. 19) "grows luxuriantly in warm temperatures and slowly in the coldest temperatures in which the fruit can be stored safely without freezing." (See also 3, pl. 1, D, and pl. 3.)

The fact that berries destroyed by Botrytis are frequently brownish when they arrive at their destination has caused some inspectors to apply the term "brown-rot" to this disease. This name is, however, unfortunate, since it is now customarily limited in application to a different class of diseases.

In striking contrast to strawberries rotted by Rhizopus, those affected by Botrytis are even firmer than normal berries, retaining their shape even after abundant spores are produced and finally becoming hard and dry. For this reason, therefore, and because Botrytis is a field trouble rather than a rot of berries in shipment, it seems that the descriptive term "dry-rot," already in use among growers in some sections, might well be applied to this disease.

RELATION OF BOTRYTIS TO INFECTION BY RHIZOPUS.

In his first paper dealing with decay of strawberries in transit, F. L. Stevens regarded Botrytis as a primary cause of decay in transit and stated that "Botrytis initiates the decay, opening the way to such other saprophytes as may be present. Of such saprophytes Rhizopus is by far the most prominent and most abundant." On the basis of a histological study of strawberries infected with these two fungi, one of the writers stated in 1916 that Rhizopus ordinarily entered strawberries through wounds and was "not dependent on the presence of any other fungus in its attack on strawberries during shipment and on the market" (10, p. 366). It was, of course, recognized at this time that these observations did "not preclude the possibility of *Rhizopus* sp. following in an area originally infected by

Botrytis sp. or some other fungus." Continued study (12, p. 9) convinced the writers that the most common method of entrance of Rhizopus was through wounds.

Later investigations (8 and 9) led Stevens to modify his earlier views, and in a paper published jointly with Peterson he states (9, p. 264) that "*Rhizopus nigricans* is the fungus which, at the destination of the berry, is most in evidence and the fungus which, in reality, does most of the damage to shipped berries. * * * It is evident that this fungus does not attack sound berries, but is secondary in its nature, following one or another of the fungi mentioned above or gaining entrance through some mechanical wound." So far as concerns the importance of Rhizopus and the possibility of its entering through wounds, this is in substantial agreement with the observations of the writers.

Until the spring of 1917 no good opportunity was afforded for studying the effect on Rhizopus infection of previous infection by Botrytis. It seemed entirely probable, however, that Botrytis was of no particular advantage in the entrance of Rhizopus, since Rhizopus is very abundant in strawberries in which there is no Botrytis infection.

During the epidemic of Botrytis on strawberries of the Russell variety in the field at Hammond, La., already described, and in connection with the experiments on shipping washed and unwashed strawberries, advantage was taken of the opportunity to test the shipping quality of berries from a field badly infected with Botrytis as compared with that of berries from a field in which little Botrytis appeared. A single crate was filled, half with berries from the field of Klondikes in which there was little Botrytis and half with berries from the field of Russells in which Botrytis was so common. These boxes were chosen at random from lots which had been sorted and packed in the ordinary commercial manner. Half of each variety were dipped and half left as checks. All were then shipped to Chicago under refrigeration. The results are presented in Table III, tests 1 and 2.

While this observation is, of course, complicated by the fact that different varieties were used in the two cases, it at least shows that there was no marked increase in the amount of Rhizopus present in the berries which came from a field badly infected by Botrytis.

Further evidence as to the relation between these fungi was obtained by actual inoculation of infected fruit from the same field. Berries naturally infected with Botrytis were inoculated with spores and mycelium of Rhizopus from pure culture. Berries which had only small areas infected with Botrytis were readily inoculated with Rhizopus in the remaining sound tissue. In no case was infection secured when Rhizopus was inoculated into an area already infected by Botrytis.

During the experimental shipment between Monett, Mo., and St. Paul, Minn., some berries attacked by Botrytis were kept in a warm car, some were exposed to the air, and others were surrounded by leaky berries on which *Rhizopus nigricans* was fruiting. While a few of the diseased berries became infected with Rhizopus, the percentage of such infections was smaller than in the case of uninfected berries kept under similar conditions as checks. Most of the berries infected with Botrytis, on the contrary, became brown in color, firm in texture, and retained their shape for a week or more except for some slight shriveling.

At Hammond, La., on April 25, 1917, boxes of apparently sound berries and also of berries infected with Botrytis were selected. These were held at room temperature, without refrigeration, for 48 hours and then examined. Of the berries which had been apparently sound, 79 per cent were now typical leaks and 9 per cent showed soft spots due to Rhizopus infection. The berries which had shown lesions of Botrytis, on the other hand, now contained only 19 per cent of leaky berries and 9 per cent which showed small Rhizopus infections. In no cases were the latter apparently associated with the Botrytis infections. This seemed to indicate that the presence of Botrytis inside the berry actually inhibited to some extent the growth of Rhizopus.

It is, of course, not impossible that Rhizopus may follow in a region infected by Botrytis. Since, however, the writers have not been able to find a case of this sort or to produce it artificially, it may perhaps be fairly assumed that this type of infection is relatively rare.

SUMMARY.

Leak, caused by *Rhizopus nigricans*, is by far the most important rot of strawberries after picking.

Losses from leak can be most effectively reduced by keeping berries at low temperatures and by handling them carefully.

Berries picked in the early morning are cool and less likely to decay than those picked during the heat of the day.

Adequate refrigeration greatly reduces the rate of growth of *Rhizopus nigricans* in transit.

Washing strawberries to remove dirt may have a beneficial effect if the berries are washed in clean water, handled with care, packed in the crates while still wet, and refrigeration is not too long delayed. Less bruising results if the berries are packed in boxes and then washed by dipping the entire box or by running water through it than if the berries are washed before packing and plating.

Botrytis sp. is characteristically a field rot of strawberries. It is most abundant and serious in the field under conditions of excessive moisture.

Berries affected with Botrytis can be recognized at the time of picking and packing and should not be included in fruit intended for market.

Although Botrytis is able to grow at low temperatures and frequently produces abundant aerial hyphæ on strawberries in refrigerator cars, its growth on ripe berries is so slow that it is of minor importance as a cause of rot in transit.

It is evident that the entrance of Rhizopus into strawberries and the production of leak are not dependent upon previous infection by Botrytis.

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A. C. TRUE, Director.

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DIGESTIBILITY OF SOME SEED OILS.[1]

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INTRODUCTION.

It was pointed out in the initial paper[2] of this series that while the information available regarding the digestibility of the various proteins and carbohydrates was quite extensive, much less attention had been given to the determination of the digestibility of the fats.

Not only is the information regarding the digestibility of edible fats limited but even when studies have been reported they were seldom made under uniform conditions which permit of comparison. Accordingly, this investigation was undertaken to obtain the coefficients of digestibility of a large number of the edible fats, under experimental conditions, as nearly as possible identical for all the fats studied.

Attention was first given to the animal fats, and the earlier papers[3] of this series contain reports of studies of the digestibility of lard, beef fat, mutton fat (kidney fats), butter, cream, and chicken, goose, egg yolk, brisket, and fish fats. The results indicate that all were well digested when eaten in amounts not in excess of those consumed in the ordinary dietary. More recent papers report studies of the digestibility of some of the better-known vegetable fats, including olive, cottonseed, peanut, coconut, and sesame oils and cocoa butter,[1] and oils expressed from the following common nuts: Almond, black walnut, Brazil nut, butternut, English walnut, hickory nut, and pecan.[2] The results showed that when incorporated in a simple mixed diet these fats could be eaten in fairly large quantities without digestive disturbances and were very completely digested.

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[1] Prepared under the direction of C. F. Langworthy, Chief, Office of Home Economics.

[2] U. S. Dept. Agr. Bul. 310 (1915), pp. 22.

[3] U. S. Dept. Agr. Buls. 310 (1915), 507 (1917).

NOTE.—This bulletin records studies of the digestibility of corn oil, soy-bean oil, sunflower-seed oil, Japanese mustard-seed oil, rapseed oil, and charlock oil. It is primarily of interest to students and investigators of food problems.

In continuation of these investigations this paper reports studies of the thoroughness of digestion of corn, soy-bean, sunflower-seed, Japanese mustard-seed, rapeseed, and charlock-seed oils. Edible corn oil has been on the market for a number of years, but the other oils of this group have been used in this country for food purposes in only a limited way as compared with olive, cottonseed, peanut, and coconut oils. However, all of these oils are so used in other countries and their oil-bearing seeds are produced to a greater or less extent in the United States.

For the purpose of this investigation good grades of corn, rape, and charlock oils were purchased in the open market. The sunflower oil (supplied by the Drug Plant Laboratories of the Bureau of Plant Industry) was expressed at a commercial mill from seed grown under known conditions. The mustard and soy-bean oils were expressed from first-quality seed in the laboratories of the Bureau of Chemistry. All of these oils were assumed to be representative of those ordinarily procured by the average consumer. In order that the oil of each kind studied should be of uniform composition, a quantity sufficient for the purpose of the investigation was obtained at the beginning of the experimental work and was thoroughly mixed before it was used for the test reported here.

EXPERIMENTAL METHODS.

The same experimental methods were employed in this investigation as in the studies previously reported, so that the coefficients of digestibility here reported should be directly comparable with those obtained for the fats already studied. The fat was incorporated in a cornstarch pudding or blancmange, which was heavily flavored with caramel to mask any characteristic flavor of the fat under consideration. A sufficient quantity of blancmange to supply all the subjects for the entire test was prepared at the beginning of the experimental period. It was very thoroughly mixed in order to insure uniform composition and a sample was reserved for analysis. This blancmange formed the principal part of a simple mixed diet, the foods eaten with it including wheat biscuits, oranges, and sugar, with tea or coffee, if a beverage other than water was desired. Previous experiments have shown that such a diet is reasonably palatable and especially suited to a study of this character.

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[1] U. S. Dept. Agr. Bul. 505 (1917).

[2] U. S. Dept. Agr. Bul. 630 (1918).

Other experimental conditions were the same as in the earlier digestion experiments with fats in which a 3-day or 9-meal test period proved entirely satisfactory, since it allowed the use of sufficient quantities of fat to give accurate results but was not so long that the diet became too monotonous. The test period was generally followed by a rest period of 4 days, during which the subjects were permitted to follow their usual dietary routine. The subjects of the digestion experiments were medical or dental students from 20 to 40 years of age, moderately active, of good health, and normal appetites. With one or two exceptions they had served as subjects of experiments previously reported, and in every instance were trustworthy and carried out carefully the directions given them. The diet during the experimental periods was limited to the prescribed ration and the subjects were instructed to reserve all uneaten portions of the diet for reweighing, and to observe care in the separation and collection of the feces.

The total amounts of food eaten were recorded, as well as the weight of the feces, and samples of both food and feces were analyzed. From the amount and composition of food and feces the percentages of protein, fat, and carbohydrates digested were calculated. Although the subjects were not required to eat any specified amount of food, it was desired that the weight of fat consumed daily should approximate that eaten in the earlier experiments (about 100 grams per man per day) in order that it would be possible to compare the physiological action of like amounts of edible fats. In general, the greater part of the food served was eaten without comment, showing that it was acceptable to the subjects. Though no special effort was made to determine the limit of tolerance of any of the fats under consideration the tests furnish data regarding it.

CORN OIL.

In the commercial manufacture of cornstarch and other corn products the germ is removed from the corn and remains as a by-product. When subjected to pressure the germ, which is more than half fat, yields an oil which has been used for some time for technical and also for culinary purposes. In a review of the present commercial production of corn oil Bailey[1] says that, as a result of the perfection of the methods of manufacture, and the careful separation of the germ, a very satisfactory edible oil is produced. Edible corn oil has been used quite extensively in the preparation of lard substitutes and it is now becoming quite a common household product.

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[1] U. S. Dept. Agr., Yearbook Sept. 691.

In view of the very large amount of this oil that is produced annually, its value for edible purposes is a matter of very considerable interest. McPherson and Ruth[1] studied the possibility of the use of corn oil for shortening purposes and found that pastry made with mixtures of lard and corn oil in amounts not exceeding 10 per cent of the latter was identical in quality with pastry in which lard alone was used. Ritter[2] in a report of a study of the use of corn oil as a fat food in the treatment of tuberculosis states: "The ingestion of corn oil is well tolerated * * * and the prolonged and increasing dosage is always well borne by the stomach."

In the determination of the digestibility of a number of edible fats Moore[3] found that guinea pigs fed on wheat bran on which corn oil had been blown in a fine spray digested 86.47 per cent of the corn oil.

In order that the corn oil studied should be representative of corn oil as purchased by the average consumer two lots manufactured by different concerns were purchased on the open market at different seasons of the year. Both of these oils were stored under laboratory conditions for a time before being used for the tests here reported. Experiments Nos. 389, 390, 391, and 392 were made with one of the oils and experiments Nos. 689, 690, and 691 were made with the second oil. Since no marked differences were noted, it is to be assumed that the oils were very similar in their physiological action.

Seven experiments in which different subjects assisted are herewith reported, the data being summarized in the following tables:

Data of digestion experiments with corn oil in a simple mixed diet.

Experiments, subjects, and diet.	Weight of food.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 389, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing corn oil	1,983.0	901.1	37.1	247.3	786.2	11.3
Wheat biscuit	485.0	43.6	51.4	7.3	374.9	7.8
Fruit	831.0	722.1	6.6	1.7	96.4	4.2
Sugar	81.0				81.0	
Total food consumed	3,380.0	1,666.8	95.1	256.3	1,338.5	23.3
Feces	94.0		31.1	15.3	39.1	8.5
Amount utilized			64.0	241.0	1,299.4	14.8
Per cent utilized			67.3	94.0	97.1	63.5
Experiment No. 390, subject A. J. H.:						
Blancmange containing corn oil	2,571.0	1,168.3	48.1	320.6	1,019.4	14.6
Wheat biscuit	561.0	50.5	59.4	8.4	433.7	9.0
Fruit	1,406.0	1,221.8	11.3	2.8	163.1	7.0
Sugar	27.0				27.0	
Total food consumed	4,565.0	2,440.6	118.8	331.8	1,643.2	30.6
Feces	101.0		31.7	18.3	40.5	10.5
Amount utilized			87.1	313.5	1,602.7	20.1
Per cent utilized			73.3	94.5	97.5	65.7

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[1] Ann. Rpt. Ohio Dairy and Food Comr., 21 (1906), pp. 18–23.

[2] Jour. Amer. Med. Assoc., 51 (1908), No. 1, pp. 39, 40.

[3] Arkansas Sta. Bul. 78 (1903), pp. 33–41.

Data of digestion experiments with corn oil in a simple mixed diet—Continued.

Experiments, subjects, and diet.	Weight of food.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 391, subject R. L. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing corn oil	1,615.0	733.9	30.2	201.4	640.3	9.2
Wheat biscuit	234.0	21.1	24.8	3.5	180.9	3.7
Fruit	557.0	484.0	4.5	1.1	64.6	2.8
Sugar	49.0				49.0	
Total food consumed	2,455.0	1,239.0	59.5	206.0	934.8	15.7
Feces	55.0		18.3	12.5	18.1	6.1
Amount utilized			41.2	193.5	916.7	9.6
Per cent utilized			69.2	93.9	98.1	61.1
Experiment No. 392, subject O. E. S.:						
Blancmange containing corn oil	1,748.0	794.3	32.7	218.0	693.1	9.9
Wheat biscuit	356.0	32.1	37.7	5.3	275.2	5.7
Fruit	984.0	855.1	7.9	2.0	114.1	4.9
Sugar	181.0				181.0	
Total food consumed	3,269.0	1,681.5	78.3	225.3	1,263.4	20.5
Feces	95.0		31.2	13.5	39.2	11.1
Amount utilized			47.1	211.8	1,224.2	9.4
Per cent utilized			60.2	94.0	96.9	45.9
Experiment No. 689, subject P. K.:						
Blancmange containing corn oil	1,892.0	829.5	37.8	263.6	746.2	14.9
Wheat biscuit	318.0	28.6	33.7	4.8	245.8	5.1
Fruit	424.0	368.5	3.4	0.8	49.2	2.1
Sugar	156.0				156.0	
Total food consumed	2,790.0	1,226.6	74.9	269.2	1,197.2	22.1
Feces	71.0		22.5	13.8	28.1	6.6
Amount utilized			52.4	255.4	1,169.1	15.5
Per cent utilized			70.0	94.9	97.7	70.1
Experiment No. 690, subject A. A. R.:						
Blancmange containing corn oil	1,815.0	795.7	36.3	252.8	715.9	14.3
Wheat biscuit	131.0	11.8	13.9	2.0	101.2	2.1
Fruit	1,198.0	1,041.0	9.6	2.4	139.0	6.0
Sugar	124.0				124.0	
Total food consumed	3,268.0	1,848.5	59.8	257.2	1,080.1	22.4
Feces	96.0		36.6	14.2	37.3	7.9
Amount utilized			23.2	243.0	1,042.8	14.5
Per cent utilized			38.8	94.5	96.5	64.7
Experiment No. 691, subject W. E. T.:						
Blancmange containing corn oil	903.0	395.9	18.1	125.8	356.1	7.1
Wheat biscuit	270.0	24.3	28.6	4.1	208.7	4.3
Fruit	1,006.0	874.2	8.1	2.0	116.7	5.0
Sugar	209.0				209.0	
Total food consumed	2,388.0	1,294.4	54.8	131.9	890.5	16.4
Feces	65.0		20.7	15.1	22.2	7.0
Amount utilized			34.1	116.8	868.3	9.4
Per cent utilized			62.2	88.6	97.5	57.3
Average food consumed per subject per day	1,053.0	542.7	25.8	79.9	397.5	7.2

Summary of digestion experiments with corn oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
389	D. G. G	67.3	94.0	97.1	63.5
390	A. J. H	73.3	94.5	97.5	65.7
391	R. L. S	69.2	93.9	98.1	61.1
392	O. E. S	60.2	94.0	96.9	45.9
689	P. K	70.0	94.9	97.7	70.1
690	A. A. R	38.8	94.5	96.5	64.7
691	W. E. T	62.2	88.6	97.5	57.3
	Average	63.0	93.5	97.3	61.2

On an average the subjects ate 26 grams of protein, 80 grams of fat, and 398 grams of carbohydrates. The fuel value of the diet was 2,415 calories. The total fat of the diet, approximately 97 per cent of which was corn oil, was 93.5 per cent digested. When the usual correction for the undigested fat of the basal ration and metabolic products is made, the value 93.5 per cent for the digestibility of the total fat of the diet becomes 96.9 per cent for the digestibility of corn oil alone. In these as in all other tests, except those with charlock oil, the fat-rich blancmange was eaten readily and without comment, showing that the oil as used was not unpalatable. The proteins and carbohydrates supplied by the diet were 63 per cent and 97 per cent digested, respectively, values which correspond with those obtained for these constituents in earlier experiments of this series.

In the reports which the subjects submitted regarding their physical condition during the experimental periods, no reference was made to any laxative effect resulting from the diet. On the basis of the results of the tests reported it may be reasonably concluded that refined corn oil, when eaten in amounts comparable with the amount of fat occurring in the average dietary, served satisfactorily for food purposes.

SOY-BEAN OIL.

The soy bean (*Glycine soja*), prepared in a variety of ways, has long been a staple article of diet in the oriental countries, ranking very close to rice in order of importance. As a result of the long-continued use of this legume for food purposes, the oriental peoples have developed many special ways of using the protein and carbohydrate of the soy bean, some with and some without the oil. Though used for fuel and illuminating purposes in the Orient, much less attention seems to have been given to the dietary use of the separated soy-bean oil.

In the United States constantly increasing quantities of soy beans, imported from the Orient or produced for the most part in the cotton-growing districts, are pressed in the cottonseed-oil mills. The oil is largely used for technical purposes, especial attention having been given to its use as a paint oil. Work which has been done indicates that the characteristic odor and taste of the crude oil can be nearly, if not entirely, eliminated by careful refining and that the refined oil may be used for food purposes.

Korenchevsky and Zimmerman[1] made a study of the digestibility of soy-bean oil when eaten with a basal ration of rye bread, cabbage soup, and buckwheat or millet cooked as porridge. Three soldiers of normal health served as subjects and ate 100 grams of soy-bean oil daily, in addition to the 46 grams of fat supplied by the basal ration. The total fat of the diet was on the average 97 per cent digested. In a study of the digestibility of tofu (a soy-bean cheese), Oswa and Ueda[1] found the fat of the diet was 97.4 per cent digested. The fat eaten during this experiment was entirely supplied by the soy-bean tofu. In two experiments with a similar diet in which the tofu supplied all the fat eaten, Kano and Iishima[2] report that the fat was 95.3 per cent and 84.3 per cent digested respectively. Suchi[3] conducted an experiment to determine the digestibility of a diet of cooked rice and cooked tofu in which 93 per cent of the fat of the diet was furnished by the tofu and found that the fat was 96.5 per cent digested. On a diet consisting of rice, tofu, sugar, starch, and shoyu (soy sauce) in which 99 per cent of the total fat of the diet was furnished by tofu Osawa[4] found that the fat was 94.8 per cent digested.

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[1] Viestnik Obshch. Hig., Sudeb. i Prakt. Med., 1905, pp. 690–693.

Since some difficulty was experienced in securing soy-bean oil free from marked odor or taste, it was decided to express oil from cleaned mammoth yellow soy beans which had been grown under known conditions by the Bureau of Plant Industry. Through the courtesy of H. S. Bailey, oil specialist of the Bureau of Chemistry, the oil was expressed in a continuous process expeller type of oil press under conditions approximating quite closely those of the commercial oil mill. The cold-pressed oil obtained was filtered and used without any refining. It was incorporated in the usual cornstarch blancmange and served as a part of the experimental diet.

Seven experiments were made with soy-bean oil and the results which were obtained are reported in the following tables:

Data of digestion experiments with soy-bean oil in a simple mixed diet.

Experiments, subjects, and diet.	Weight of food.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 432, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing soy-bean oil	1,348.0	633.9	23.6	167.3	512.8	10.4
Wheat biscuit	300.0	27.0	31.8	4.5	231.9	4.8
Fruit	1,173.0	1,019.3	9.4	2.3	136.1	5.9
Sugar	188.0	....	....	....	188.0	....
Total food consumed	3,009.0	1,680.2	64.8	174.1	1,068.8	21.1
Feces	100.0	....	32.3	11.3	48.7	7.7
Amount utilized	....	....	32.5	162.8	1,020.1	13.4
Per cent utilized	....	....	50.2	93.5	95.4	63.5

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[1] U. S. Dept. Agr., Office Expt. Stas. Bul. 159 (1905), p. 150.

[2] U. S. Dept. Agr., Office Expt. Stas. Bul. 159 (1905), p. 172. [Gun-i Gakko Gyofu (Bul. Army Med. Col), Tokyo, 1899, No. 3, p. 101.]

[2] U. S. Dept. Agr. Office Expt. Stas. Bul. 159 (1905), p. 152 [Tokoy Igakukuwai Zashsi (Jour. Tokyo Med. Soc.), 2 (1888), pp. 457, 511.]

[4] U. S. Dept. Agr., Office Expt. Stas. Bul. 159 (1905), p. 154 [Chugai Iji Shimpo (Med. News, foreign and domestic), Tokyo, 1889, No. 211, p. 6.]

Data of digestion experiments with soy-bean oil in a simple mixed diet.—Contd.

Experiments, subjects, and diet.	Weight of food.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 433, subject A. J. H.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing soy-bean oil	2,472.0	1,162.6	43.3	306.8	940.3	19.0
Wheat biscuit	138.0	12.4	14.6	2.1	106.7	2.2
Fruit	1,048.0	910.7	8.4	2.1	121.6	5.2
Sugar	159.0				159.0	
Total food consumed	3,817.0	2,085.7	66.3	311.0	1,327.6	26.4
Feces	106.0		35.2	23.6	37.2	10.0
Amount utilized			31.1	287.4	1,290.4	16.4
Per cent utilized			46.9	92.4	97.2	62.1
Experiment No. 434, subject R. L. S.:						
Blancmange containing soy-bean oil	1,682.0	791.1	29.4	208.7	639.8	13.0
Wheat biscuit	274.0	24.7	29.0	4.1	211.8	4.4
Fruit	571.0	496.2	4.6	1.1	66.2	2.9
Sugar	107.0				107.0	
Total food consumed	2,634.0	1,312.0	63.0	213.9	1,024.8	20.3
Feces	82.0		27.1	14.8	30.9	9.2
Amount utilized			35.9	199.1	993.9	11.1
Per cent utilized			57.0	93.1	97.0	54.7
Experiment No. 435, subject O. E. S.:						
Blancmange containing soy-bean oil	1,670.0	785.4	29.2	207.2	635.3	12.9
Wheat biscuit	220.0	19.8	23.3	3.3	170.1	3.5
Fruit	1,204.0	1,046.3	9.6	2.4	139.7	6.0
Sugar	203.0				203.0	
Total food consumed	3,297.0	1,851.5	62.1	212.9	1,148.1	22.4
Feces	85.0		29.4	14.9	32.7	8.0
Amount utilized			32.7	198.0	1,115.4	14.4
Per cent utilized			52.7	93.0	97.2	64.3
Experiment No. 440, subject D. G. G.:						
Blancmange containing soy-bean oil	1,398.0	649.8	26.1	214.0	494.9	13.2
Wheat biscuit	363.0	32.7	38.5	5.4	280.6	5.8
Fruit	903.0	784.7	7.2	1.8	104.8	4.5
Sugar	201.0				201.0	
Total food consumed	2,865.0	1,467.2	71.8	221.2	1,081.3	23.5
Feces	88.0		28.8	10.1	42.2	6.9
Amount utilized			43.0	211.1	1,039.1	16.6
Per cent utilized			59.9	95.4	96.1	70.6
Experiment No. 441, subject A. J. H.:						
Blancmange containing soy-bean oil	2,193.0	1,019.3	41.0	335.8	776.3	20.6
Wheat biscuit	93.0	8.4	9.8	1.4	71.9	1.5
Fruit	1,086.0	943.7	8.7	2.2	126.0	5.4
Sugar	84.0				84.0	
Total food consumed	3,456.0	1,971.4	59.5	339.4	1,058.2	27.5
Feces	107.0		41.9	23.0	30.9	11.2
Amount utilized			17.6	316.4	1,027.3	16.3
Per cent utilized			29.6	93.2	97.1	59.3
Experiment No. 442, subject O. E. S.:						
Blancmange containing soy-bean oil	1,539.0	715.3	28.8	235.6	544.8	14.5
Wheat biscuit	217.0	19.5	23.0	3.3	167.7	3.5
Fruit	1,007.0	875.1	8.1	2.0	116.8	5.0
Sugar	148.0				148.0	
Total food consumed	2,911.0	1,609.9	59.9	240.9	977.3	23.0
Feces	60.0		20.9	10.0	23.4	5.7
Amount utilized			39.0	230.9	953.9	17.3
Per cent utilized			65.1	95.8	97.6	75.2
Average food consumed per subject per day	1,047.1	570.4	21.3	81.6	366.0	7.8

Summary of digestion experiments with soy-bean oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
432	D. G. G	50.2	93.5	95.4	63.5
433	A. J. H.	46.9	92.4	97.2	62.1
434	R. L. S.	57.0	93.1	97.0	54.7
435	O. E. S.	52.7	93.0	97.2	64.3
440	D. G. G	59.9	95.4	96.1	70.6
441	A. J. H.	29.6	93.2	97.1	59.3
442	O. E. S.	65.1	95.8	97.6	75.2
	Average	51.6	93.8	96.8	64.2

It is shown in the summary of the data reported above for the seven experiments with soy-bean oil that on an average the subjects ate 21 grams of protein, 82 grams of fat, and 366 grams of carbohydrates, and that coefficients of digestibility of these constituents supplied by the diet as a whole were for protein 51.6 per cent, for fat 93.8 per cent, and for carbohydrates 96.8 per cent. The fuel value of the diet was 2,285 calories.

The values obtained for the digestibility of total fat in the individual experiments agree fairly closely with one another, the majority being within 1 per cent of the average value 93.8 per cent.

In a series of experiments[1] in which the basal ration was eaten without the addition of fat it was found that the feces resulting contained a certain amount of ether-soluble material. When allowance is made in the above data for the ether extract of the feces not resulting from the soy-bean oil the value 93.5 per cent becomes 97.5 per cent for the digestibility of soy-bean oil alone.

Since the subjects reported no unusual physiological effects as a result of this diet, and in view of the very complete utilization of soy-bean oil by the body, it would seem that well-refined soy-bean oil should prove a satisfactory food, and could be used in the same manner and quantities as other oils commonly used in the diet.

SUNFLOWER-SEED OIL.

It is well known that the seeds of the sunflower (*Helianthus annuus*), when subjected to pressure, yield a light yellow oil having properties quite similar to those of the common vegetable oils. Sunflower-seed oil, which was used by American Indians for food purposes,[2] is now little used as a food oil in the United States, the probable reason being the demand for the seed for poultry feeding and the large supply of other better-known oils. In some of the

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[1] U. S. Dept. Agr. Bul. 310 (1915), p. 17.

[2] Iroquois Foods and Food Preparation, Can. Dept. Mines, Geol. Survey, 86 (1916), p. 100.

European countries, however, this oil is quite extensively used and is an important constitutent of the dietary. According to Lewkowitsch[1] the sunflower is largely grown in southern Russia and the cold-pressed oil is used there for culinary purposes and for margarin manufacture.

As the production of sunflower seed in this country may be materially increased, and since no tests of the digestibility of this oil were found on record, the experiments here reported were made to determine the digestibility of sunflower-seed oil when eaten as a constituent of a uniform diet such as was served during the test periods with the edible fats previously studied.

The data of the digestion experiments with sunflower-seed oil are included in the following tables:

Data of digestion experiments with sunflower-seed oil in a simple mixed diet.

Experiments, subjects, and diet.	Weight of food.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 597, subject A. J. H.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing sunflower-seed oil	1,706.0	752.7	61.2	245.2	633.9	13.0
Wheat biscuit	266.0	23.9	28.2	4.0	205.6	4.3
Fruit	30.0	26.1	.2	.1	3.5	.1
Sugar						
Total food consumed	2,002.0	802.7	89.6	249.3	843.0	17.4
Feces	64.0		22.7	11.9	22.6	6.8
Amount utilized			66.9	237.4	820.4	10.6
Per cent utilized			74.7	95.2	97.3	60.9
Experiment No. 598, subject P. K.:						
Blancmange containing sunflower-seed oil	2,326.0	1,026.2	83.5	334.3	864.3	17.7
Wheat biscuit	365.0	32.9	38.7	5.5	282.1	5.8
Fruit	706.0	613.5	5.7	1.4	81.9	3.5
Sugar	202.0				202.0	
Total food consumed	3,599.0	1,672.6	127.9	341.2	1,430.3	27.0
Feces	88.0		24.3	24.0	33.5	6.2
Amount utilized			103.6	317.2	1,396.8	20.8
Per cent utilized			81.0	93.0	97.7	77.0
Experiment No. 599, subject J. C. M.:						
Blancmange containing sunflower-seed oil	1,578.0	696.2	56.6	226.8	586.4	12.0
Wheat biscuit	236.0	21.2	25.0	3.6	182.4	3.8
Fruit	972.0	844.7	7.8	1.9	112.7	4.9
Sugar	109.0				109.0	
Total food consumed	2,895.0	1,562.1	89.4	232.3	990.5	20.7
Feces	61.0		17.0	11.7	27.2	5.1
Amount utilized			72.4	220.6	963.3	15.6
Per cent utilized			81.0	95.0	97.3	75.4
Experiment No. 600, subject C. J. W.:						
Blancmange containing sunflower-seed oil	1,910.0	842.7	68.6	274.5	709.7	14.5
Wheat biscuit	308.0	27.7	32.7	4.6	238.1	4.9
Fruit	948.0	823.8	7.6	1.9	110.0	4.7
Sugar	118.0				118.0	
Total food consumed	3,284.0	1,694.2	108.9	281.0	1,175.8	24.1
Feces	102.0		31.9	22.8	36.9	10.4
Amount utilized			77.0	258.2	1,138.9	13.7
Per cent utilized			70.7	91.9	96.9	56.8
Average food consumed per subject per day	981.7	477.6	34.7	92.0	370.0	7.4

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[1] Chemical Technology and Analysis of Oils, Fats, and Waxes. London: Macmillan and Co., Limited, 1909, vol. 2, pp. 103–105.

Summary of digestion experiments with sunflower-seed oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
597	A. J. H	74.7	95.2	97.3	60.9
598	P. K	81.0	93.0	97.7	77.0
599	J. C. M	81.0	95.0	97.3	75.4
600	C. J. W	70.7	91.9	96.9	56.8
	Average	76.9	93.8	97.3	67.5

The data of the above experiments indicate that the subjects ate on an average 92 grams of fat daily during the test periods and that this was 93.8 per cent digested. Approximately 98 per cent of the total fat eaten, or 90 grams daily, was sunflower-seed oil. When allowance is made for the metabolic products and the unutilized fat resulting from the fat of the basal ration, the value 93.8 per cent obtained for the digestibility of the total fat of the diet becomes 96.5 per cent for the digestibility of sunflower oil alone.

The diet as a whole supplied 35 grams of protein, 92 grams of fat, and 370 grams of carbohydrates per man per day, the average fuel value being 2,450 calories.

The subjects reported that they were in normal physical condition throughout the experimental period which would indicate that the limit of tolerance for sunflower-seed oil is in excess of a consumption of 90 grams daily, and that this amount is well assimilated by the body.

JAPANESE MUSTARD-SEED OIL.

Commercial mustard-seed oil occurs as a by-product of the manufacture of mustard used for condimental purposes and was formerly obtained from the seeds of a variety of mustard plants or from a mixture of seeds of different varieties. As a result of the present unsettled commercial conditions, little if any of those varieties of mustard seed formerly used for condimental purposes is now imported into this country. In order to meet the demand for mustard the manufacturers have employed the yellow Japanese mustard seed to quite an extent, and as a consequence the amount of Japanese mustard-seed oil on the market has been very greatly increased.

The seeds of the Japanese mustard (*Brassica cernua*) when subjected to pressure yield a light, brownish-yellow oil, having much the same characteristics as the common edible oils, and while little used in this country for edible purposes, should be considered as of interest from the standpoint of an edible oil.

No reports of the determination of the digestibility of this oil were found in the literature consulted. The oil used in these experiments was expressed in the laboratories of the Bureau of Chemistry from a good grade of cleaned mustard seed imported by that bureau. While it was expressed under laboratory rather than under commercial conditions, it was assumed to be quite similar to the commercial mustard-seed oil.

The results of the tests made with unrefined oil are summarized in the following tables:

Data of digestion experiments with Japanese mustard-seed oil in a simple mixed diet.

Experiments, subjects, and diet.	Weight of food.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 615, subject P. K.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing mustard-seed oil	2,267.0	1,254.8	69.4	264.1	504.2	174.5
Wheat biscuit	401.0	36.1	42.5	6.0	310.0	6.4
Fruit	661.0	574.4	5.3	1.3	76.7	3.3
Sugar	203.0				203.0	
Total food consumed	3,532.0	1,865.3	117.2	271.4	1,093.9	184.2
Feces	87.0		24.1	12.2	44.8	5.9
Amount utilized			93.1	259.2	1,049.1	178.3
Per cent utilized			79.4	95.5	95.9	96.8
Experiment No. 616, subject J. C. M.:						
Blancmange containing mustard-seed oil	1,842.0	1,019.5	56.4	214.6	409.7	141.8
Wheat biscuit	287.0	25.8	30.4	4.3	221.9	4.6
Fruit	1,099.0	955.0	8.8	2.2	127.5	5.5
Sugar	126.0				126.0	
Total food consumed	3,354.0	2,000.3	95.6	221.1	885.1	151.9
Feces	101.0		27.7	7.5	57.6	8.2
Amount utilized			67.9	213.6	827.5	143.7
Per cent utilized			71.0	96.6	93.5	94.6
Experiment No. 617, subject C. J. W.:						
Blancmange containing mustard-seed oil	2,001.0	1,107.6	61.2	233.1	445.0	154.1
Wheat biscuit	339.0	30.5	36.0	5.1	262.0	5.4
Fruit	943.0	819.5	7.5	1.9	109.4	4.7
Sugar	115.0				115.0	
Total food consumed	3,398.0	1,957.6	104.7	240.1	931.4	164.2
Feces	124.0		40.6	17.7	54.2	11.5
Amount utilized			64.1	222.4	877.2	152.7
Per cent utilized			61.2	92.6	94.2	93.0
Average food consumed per subject per day	1,142.7	647.0	35.3	81.4	323.4	55.6

Summary of digestion experiments with Japanese mustard-seed oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
615	P. K.	79.4	95.5	95.9	96.8
616	J. C. M.	71.0	96.6	93.5	94.6
617	C. J. W.	61.2	92.6	94.2	93.0
	Average	70.5	94.9	94.5	94.8

The average coefficient of digestibility of the total fat of the diet was found to be 94.9 per cent. While the subjects on an average ate only 81 grams of fat daily, over 97 per cent was mustard-seed oil and the value for the digestibility of the total fat is increased when allowance is made for the ether extract of the feces resulting from the basal diet to 95.8 per cent for the digestibility of mustard-seed oil alone.

No attempt was made to feed larger quantities of the oil in order to secure data in regard to the limit of tolerance of the body for mustard-seed oil. In two of the experiments, Nos. 615 and 616, the subjects reported a slight diarrhea, and so it would seem that the limit of tolerance for this oil was not much in excess of 87 grams daily, the amount of mustard oil eaten by one of the subjects. It is quite possible, however, that the limit of tolerance for highly refined oil might be greater than that of the unrefined oil which was used.

The protein and carbohydrates furnished by the diet were 71 per cent and 95 per cent digested, respectively, values which compare favorably with the thoroughness of digestion of these constituents usually found in earlier tests in which the same basal ration was eaten. As a whole the diet supplied 35 grams of protein, 81 grams of fat, and 323 grams of carbohydrates daily and had a fuel value of 2,160 calories.

RAPESEED OIL.

The refined rapeseed oil of commerce is of a pale yellow color, possesses a characteristic taste, and is prepared from the seeds of the rape plant (*Brassica napus*).

Though rapeseed oil is not produced in the United States to any extent for edible purposes, cold-pressed rapeseed oil is used in Europe and especially in India for food purposes. In a discussion of commercial rapeseed oil, Lewkowitsch[1] states that this oil, called "bread" oil, is largely used in England by bakers for greasing the ends of loaves of bread to prevent their sticking together when baked.

No records of any direct determinations of the digestibility of this oil have been found in the literature consulted. However, in a study of the comparative digestibility of a rice and tofu diet with and without rapeseed oil, Suchi[2] found that the total fat of the diets was 93.9 per cent and 96.5 per cent digested, respectively. The author, who served as the subject of the experiments, ate in the latter experiment approximately 58 grams of fat daily, this amount being supplied by the rice and tofu, and in the former ate 126 grams of fat daily, of which 57 grams was rapeseed oil. Bertarelli[1] conducted a series of digestion experiments to determine the relative nutritive value of margarin and butter and included an experiment in which the subject ate an average of 910 grams of white bread, 250 grams of meat, and 61.6 grams of a mixture of olive and colza (or rapeseed) oils. He found the total fat of the diet to be 95.82 per cent digested.

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[1] Chemical Technology and Analysis of Oils, Fats, and Waxes. London: Macmillan and Co., Limited, 1909, vol. 2, p. 205.

[2] U. S. Dept. Agr., Office Expt. Stas. Bul. 159 (1905), p. 153. [Tokyo Igakukwai Zasshi (Jour. Tokyo Med. Soc.), 2 (1888), pp. 457, 511.]

The oil used in the experiments here reported was purchased in the open market and was taken to be representative of the edible rapeseed oil of commerce. The following tables contain the data obtained during the test periods with rapeseed oil:

Data of digestion experiments with rapeseed oil in a simple mixed diet.

Experiments, subjects, and diet.	Weight of food.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 629, subject A. F.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing rapeseed oil	2,380.0	1,575.6	90.7	262.0	274.9	176.8
Wheat biscuit	291.0	26.2	30.8	4.4	224.9	4.7
Fruit	880.0	764.7	7.0	1.8	102.1	4.4
Sugar	152.0				152.0	
Total food consumed	3,703.0	2,366.5	128.5	268.2	753.9	185.9
Feces	59.0		17.7	9.1	26.8	5.4
Amount utilized			110.8	259.1	727.1	180.5
Per cent utilized			86.2	96.6	96.4	97.1
Experiment No. 630, subject P. K.:						
Blancmange containing rapeseed oil	2,499.0	1,654.3	95.2	275.2	288.6	185.7
Wheat biscuit	364.0	32.8	38.6	5.4	281.4	5.8
Fruit	570.0	495.3	4.6	1.1	66.1	2.9
Sugar	198.0				198.0	
Total food consumed	3,631.0	2,182.4	138.4	281.7	834.1	194.4
Feces	91.0		27.3	11.4	46.3	6.0
Amount utilized			111.1	270.3	787.8	188.4
Per cent utilized			80.3	96.0	94.4	96.9
Experiment No. 631, subject J. C. M.:						
Blancmange containing rapeseed oil	1,759.0	1,164.4	67.0	193.7	203.2	130.7
Wheat biscuit	291.0	26.2	30.8	4.4	224.9	4.7
Fruit	971.0	843.8	7.8	1.9	112.6	4.9
Sugar	152.0				152.0	
Total food consumed	3,173.0	2,034.4	105.6	200.0	692.7	140.3
Feces	69.0		19.7	7.3	36.0	6.0
Amount utilized			85.9	192.7	656.7	134.3
Per cent utilized			81.3	96.4	94.8	95.7
Experiment No. 632, subject C. J. W.:						
Blancmange containing rapeseed oil	2,290.0	1,516.0	87.3	252.1	264.5	170.1
Wheat biscuit	420.0	37.8	44.5	6.3	324.7	6.7
Fruit	833.0	723.9	6.6	1.7	96.6	4.2
Sugar	98.0				98.0	
Total food consumed	3,641.0	2,277.7	138.4	260.1	783.8	181.0
Feces	112.0		36.4	16.3	51.0	8.3
Amount utilized			102.0	243.8	732.8	172.7
Per cent utilized			73.7	93.7	93.5	95.4
Average food consumed per subject per day	1,179.0	738.4	42.6	84.2	255.4	58.4

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[1] Riv. Ig. e Sanit. Pub., 9 (1898), No. 15, pp. 570–579.

Summary of digestion experiments with rapeseed oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
629	A. F.	86.2	96.6	96.4	97.1
630	P. K.	80.3	96.0	94.4	96.9
631	J. C. M.	81.3	96.4	94.8	95.7
632	C. J. W.	73.7	93.7	93.5	95.4
	Average	80.4	95.7	94.8	96.3

During the test periods with rapeseed oil the subjects ate on an average 43 grams of protein, 84 grams of fat, and 255 grams of carbohydrates daily which were 80.4 per cent, 95.7 per cent, and 94.8 per cent digested, respectively. Less than 3 per cent of the total fat eaten was supplied by the basal ration and approximately 82 grams of rapeseed oil was eaten by each subject daily. When allowance is made for that portion of the ether extract of the feces which has been shown to consist of metabolic products and undigested fat resulting from the basal ration the value 95.7 per cent obtained for the digestibility of the total fat of the diet becomes 98.8 per cent for the digestibility of rapeseed oil alone.

In their reports of their physical condition during the test periods the subjects made no mention of any laxative effects resulting from the diet and accordingly it is assumed that the limit of tolerance for rapeseed oil is somewhat in excess of 84 grams, the average amount eaten daily by the subjects during the experiments here reported.

CHARLOCK OIL.

The charlock (*Brassica arvensis*) or wild mustard is rarely, if ever, cultivated in the United States, but in some localities it appears in the grainfields to such an extent that when the grain is thrashed large quantities of charlock seed are present in the grain.

When such grain is cleaned at the elevators wheat screenings or what is commonly referred to as "dockage" by the elevator men is obtained. These screenings ordinarily contain a wide variety of weed seeds, including charlock. The charlock is later separated from the other weed seeds by the feed dealers who buy the "dockage" to obtain the wild oats and other feed seed which it contains. It has been estimated that charlock seed is obtained in this way in sufficient quantities to warrant its use for commercial purposes.

Charlock seed, when subjected to pressure, yields an oil very similar in properties to some of the common edible oils, but has, when unrefined, a harsh, unpleasant taste. Bailey and Burnett[1] studied the chemical and physical characteristics of charlock oil and state that it can be refined sufficiently to be edible but that at present it is largely used for industrial purposes.

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[1] Jour. Indus. and Engin. Chem., 8 (1916), No. 5, p. 429.

In view of its close resemblance to rape and mustard-seed oils, and since a survey of the literature revealed no information in regard to its digestibility, it seemed desirable to determine the digestibility of this oil when eaten under conditions identical with those under which the other fats have been studied. A good grade of unrefined commercial charlock-seed oil believed to be representative of that ordinarily obtained by the consumer was purchased on the open market for use in the tests.

The following tables contain the results obtained during four test periods:

Data of digestion experiments with charlock oil in a simple mixed diet.

Experiments, subjects, and diet.	Weight of food.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 641, subject A. F.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing charlock oil	2,235.0	1,178.5	57.2	192.4	795.0	11.9
Wheat biscuit	318.0	28.6	33.7	4.8	245.8	5.1
Fruit	686.0	596.1	5.5	1.4	79.6	3.4
Sugar	193.0				193.0	
Total food consumed	3,432.0	1,803.2	96.4	198.6	1,313.4	20.4
Feces	85.0		24.6	12.5	38.3	9.6
Amount utilized			71.8	186.1	1,275.1	10.8
Per cent utilized			74.5	93.7	97.1	52.9
Experiment No. 642, subject P. K.:						
Blancmange containing charlock oil	2,082.0	1,097.8	53.3	179.3	740.6	11.0
Wheat biscuit	342.0	30.8	36.2	5.1	264.4	5.5
Fruit	276.0	239.8	2.2	0.6	32.0	1.4
Sugar	102.0				102.0	
Total food consumed	2,802.0	1,368.4	91.7	185.0	1,139.0	17.9
Feces	65.0		20.1	10.5	28.7	5.7
Amount utilized			71.6	174.5	1,110.3	12.2
Per cent utilized			78.1	94.3	97.5	68.2
Experiment No. 643, subject J. C. M.:						
Blancmange containing charlock oil	1,916.0	1,010.3	49.0	165.0	681.5	10.2
Wheat biscuit	309.0	27.8	32.8	4.6	238.9	4.9
Fruit	369.0	320.7	3.0	0.7	42.8	1.8
Sugar	154.0				154.0	
Total food consumed	2,748.0	1,358.8	84.8	170.3	1,117.2	16.9
Feces	72.0		18.5	6.3	41.8	5.4
Amount utilized			66.3	164.0	1,075.4	11.5
Per cent utilized			78.2	96.3	96.3	68.0
Experiment No. 644, subject A. A. R.:						
Blancmange containing charlock oil	1,809.0	953.9	46.3	155.7	643.5	9.6
Wheat biscuit	284.0	25.6	30.1	4.3	219.5	4.5
Fruit	871.0	756.9	7.0	1.7	101.0	4.4
Sugar	252.0				252.0	
Total food consumed	3,216.0	1,736.4	83.4	161.7	1,216.0	18.5
Feces	96.0		29.1	9.5	50.3	7.1
Amount utilized			54.3	152.2	1,165.7	11.4
Per cent utilized			65.1	94.1	95.9	61.6
Average food consumed per subject per day	1,016.5	522.2	29.7	59.6	398.8	6.1

Summary of digestion experiments with charlock oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent*
641	A. F	74.5	93.7	97.1	52.9
642	P. K	78.1	94.3	97.5	68.2
643	J. C. M	78.2	96.3	96.3	68.0
644	A. A. R	65.1	94.1	95.9	61.6
	Average	74.0	94.6	96.7	62.7

Because of its pronounced odor the charlock oil was not completely masked by the caramel and vanilla used in the cornstarch blancmange in which it was incorporated. Doubtless for this reason the amounts of charlock oil eaten were small, being only 60 grams per man per day on an average. Notwithstanding its odor the subjects reported no unusual effects as a result of the experimental diet and it may be assumed that unrefined charlock oil in amounts not exceeding 60 grams daily was well tolerated. An odorless refined oil would undoubtedly have been much more acceptable.

As a whole the diet supplied 30 grams of protein, 60 grams of fat (of which 58 grams was charlock oil), and 399 grams of carbohydrates and a fuel value of 2,255 calories.

The average values obtained for the digestibility of the protein, fat, and carbohydrates supplied by the total diet were 74 per cent, 94.6 per cent, and 96.7 per cent, respectively. Making allowance for the undigested fat resulting from the basal ration and for the metabolic products, the value 94.6 per cent for the digestibility of the total fat of the diet becomes 98.9 per cent for the digestibility of charlock oil alone, which would seem to indicate that this oil was very well assimilated by the body.

SUMMARY.

The investigations on the digestibility of the seed oils here reported include seven experiments each with corn and soy-bean oils and four experiments each with sunflower-seed, Japanese mustard-seed, rapeseed, and charlock-seed oils. In each case the oils were incorporated in a cornstarch blancmange and eaten in conjunction with a uniform basal ration which supplied 2 per cent of the total fat eaten. As a result of the uniformity of the experimental methods followed, the values obtained for the different oils permit of direct comparison with one another and with the values obtained for the digestibility of the animal and vegetable fats previously reported.

During the test period in which the oils under consideration constituted practically the entire source of fat, the subjects ate on an average 82 grams of corn oil, 80 grams of soy-bean oil, 90 grams of sunflower-seed oil, 79 grams of Japanese mustard-seed oil, 82 grams of rapeseed oil, and 58 grams of charlock oil per person per day.

After allowance had been made for the metabolic products and undigested fat resulting from the basal ration, the coefficients of digestibility were found to be—for corn oil, 96.8 per cent; for soy-bean oil, 97.5 per cent; for sunflower-seed oil, 96.5 per cent; for Japanese mustard-seed oil, 98.8 per cent; for rapeseed oil, 98.9 per cent, and for charlock oil, 98.9 per cent. These values agree well with one another and with the values obtained with other vegetable oils in tests previously reported.

No attempt was made to determine the limit of tolerance of the fats, but inasmuch as the subjects did not report any physiological disturbances as a result of eating these oils, except in experiments Nos. 615 and 616 with unrefined Japanese mustard-seed oil when a slight diarrhea was reported, it would appear that the limit of tolerance for the oils was somewhat in excess of the amounts eaten.

The carbohydrate eaten during these digestion experiments consisted largely of cornstarch, which was used as an ingredient of the blancmange, of sugar eaten both separately and as an ingredient of the blancmange, and of the carbohydrate which was supplied by the wheat biscuit. The coefficients of digestibility of the carbohydrate were 97 per cent in the corn-oil tests, 97 per cent in the soy-bean-oil tests, 97 per cent in the sunflower-seed-oil tests, 95 per cent in the Japanese mustard-seed-oil tests, 95 per cent in the rapeseed-oil tests, and 97 per cent in the charlock-seed-oil tests, which indicates that the oils under consideration exerted no unusual effect on the digestibility of carbohydrates.

Considering the results of the digestion experiments as a whole it is evident that corn, soy-bean, sunflower-seed, mustard-seed, rapeseed, and charlock-seed oils are well assimilated and judged by their digestibility should prove satisfactory sources of fat for the dietary.

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Studies of the Effect of Different Methods of Cooking upon the Thoroughness and Ease of Digestion of Meats at the University of Illinois. H. S. Grindley, D. Sc., Timothy Mojonnier, M. S., and Horace C. Porter, Ph. D. Pp. 100, tables 38. 1907. (Office of Experiment Stations Bulletin 193.) Price, 15 cents.

Digestibility of Some Animal Fats. By C. F. Langworthy and A. D. Holmes. Pp. 23. 1915. (Department Bulletin 310.) Price, 5 cents.

Digestibility of Very Young Veal. By C. F. Langworthy and A. D. Holmes. Pp. 577–588. 1916. (Journal of Agricultural Research, 6 (1916), No. 16.) Price, 5 cents.

Digestibility of Hard Palates of Cattle. By C. F. Langworthy and A. D. Holmes. Pp. 641–648. 1916. (Journal of Agricultural Research, 6 (1916), No. 17.) Price, 5 cents.

Fats and Their Economical Use in the Home. By A. D. Holmes and H. L. Lang. Pp. 26. 1916. (Department Bulletin 469.) Price, 5 cents.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 688

Contribution from the Bureau of Markets
CHARLES J. BRAND, Chief

Washington, D. C. May 18, 1918

MARKETING BERRIES AND CHERRIES BY PARCEL POST.

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WHILE BERRIES AND CHERRIES are grown to some extent in all States and are shipped in carload lots from a large number of stations in 30 or more States, both producers and consumers are sometimes dissatisfied with the existing methods of marketing and distributing these fruits. Poor returns are often received for berries of good quality because of a reported glut in the market. Most growers believe that often there is no reason for glutted markets for berries and cherries of good quality and appearance, and thus they become dissatisfied with marketing conditions. Growers who must ship from points where berries are not grown in sufficient quantities to be marketed in carload lots often receive unsatisfactory returns because their fruit must be shipped without refrigeration and is sold in competition with that which is shipped from other points in refrigerator cars. While the larger part of some of the berry crops must be transported in carload lots, the agitation for direct marketing has caused many persons to become interested in the possibilities of marketing berries and cherries by parcel post. The publicity that has been given the farm-to-table campaigns conducted by postmasters in many cities has stimulated this interest.

During the season of 1915 the Bureau of Markets of the United States Department of Agriculture, in cooperation with the Post Office Department, began an investigation of shipping berries and cherries by parcel post, and many experimental shipments of strawberries, blackberries, huckleberries, raspberries, and cherries have been made This work was planned for the purpose of ascertaining whether berries and cherries could be shipped in commercial crates by parcel post, and also to determine the various factors that operate for and against the successful shipping of these fruits through the mail.

Most of the shipments were made to the Bureau of Markets from points within the first and second postal zones, which include the territory within a radius of approximately 150 miles. Few shipments were made from other zones, as most of the farm produce that will be shipped by parcel post from producers direct to consumers will not be sent beyond the second zone. Sending perishable mail matter to points beyond the second zone often is impracticable because of the higher rate of postage and the increased distance.

Inasmuch as strawberries are the most important of the small fruits, the experimental shipments that were made of this fruit were more numerous than those made of any of the other berries or of cherries. While it is realized that the experimental shipments of some of the berries were small in number and that the varying conditions make it difficult to draw definite conclusions, it is believed that sufficient work was done under enough different conditions to warrant the suggestions and conclusions here given.

STRAWBERRIES.

During three seasons 485 shipments of strawberries were made in crates of various types and sizes. The shipments totaled 9,126 quarts of 17 varieties of strawberries. On an average the berries were shipped 200 miles, while the average length of time between mailing and receipt of the shipments exceeded 20 hours. The cooperation of 63 growers located at 41 stations in 5 States was secured. Representatives from the Bureau of Markets visited these growers and observed the methods of picking, packing, and hauling the berries. Data were secured as to the time the berries were picked, the amount of handling in picking and packing, the date and hour of shipment, the weather conditions, the size of the crate, and the weight of the shipment. When the shipments were received at the Bureau of Markets the berries were examined carefully and records were made of the weight of each shipment, the date and hour received, and the condition of the container and the berries.

In making arrangements for experimental shipments, the growers were instructed that they need not give any more care or attention in picking, packing, and hauling the berries to be used in the experiments than was given ordinarily in handling the regular commercial shipments made by other means of transportation. Most of the growers who cooperated in making the experimental shipments followed these instructions, but a few who had berries of extra size and quality and were vitally interested in the success of the experiment asked and were given permission to use special care in handling their shipments. Not enough of these special shipments were made to warrant conclusions, but the results secured indicate that uncertain weather conditions and possibilities of careless handling while in transit may tend to discourage the use of the parcel post for shipping the highest grade of fancy select berries, which require special care throughout the marketing process.

Because of heavy rains and hot weather during a large part of the strawberry shipping seasons of 1916 and 1917, conditions were unfavorable for shipping berries without refrigeration. However, shipments of strawberries were made by parcel post during the entire shipping seasons, as it was desired to make experimental shipments under varying conditions.

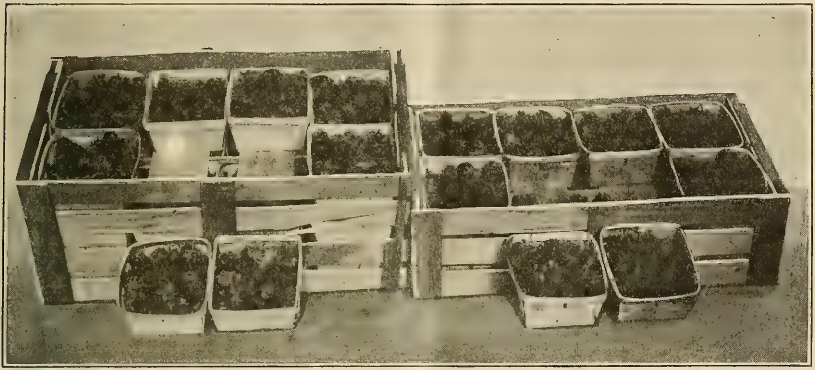

FIG. 1.—One 24-quart crate and one 16-quart crate of strawberries shipped by parcel post.

A large number of crates of berries were received in poor condition because of unfavorable weather conditions and delay in delivery. However, when the weather conditions were favorable, the berries that had been picked and packed properly arrived in good merchantable condition. Figure 1 shows two shipments of strawberries that were made under favorable conditions.

In 1915 a total of 118 crates of strawberries were received by parcel post, the fruit in all except 18 of these crates being received in good condition.

In 1916 over one-half of the shipments arrived in unsatisfactory condition, chiefly because of unfavorable weather conditions. The shipping season was marked by heavy rains, followed by hot, clear days, which caused the berries to soften and scald and made it difficult to ship them satisfactorily even under refrigeration.

During the first half of the strawberry shipping season in 1917 the weather conditions were favorable, but during the last half there were frequent rains and the nights were hot. Practically all of the shipments of strawberries that were made during the first half of the 1917 strawberry shipping season were received in very good condition, but nearly all of the shipments that were made during the last half of the season were received in unsatisfactory condition. The same methods of picking and packing the berries were practiced during the entire season, so it is evident that the difference in the condition of the berries when they were received was due almost entirely to weather conditions.

GENERAL CONSIDERATIONS.

An effort was made to ascertain the best shipping varieties of strawberries by making a special study of the shipping qualities of the different varieties that were mailed to the bureau, but because of the differences in berries of the same variety grown under different conditions it was impossible to draw any definite conclusions. Many growers had two or more kinds of strawberries in the same field and it was often difficult to determine the variety of a berry that was grown in these fields.

A grower who wishes to market strawberries direct to consumers should ship varieties the berries of which are naturally firm. Varieties with large green caps present a good appearance and often are preferred to berries which are superior in quality but which do not look so attractive. Growers should realize that consumers in buying farm produce judge quality largely by appearance, and that berries which present an attractive appearance when they reach the consumer usually will give the best satisfaction.

Many persons who market strawberries apparently do not realize that berries which are to be shipped should not be allowed to become as ripe as those which are to be used immediately. Because of weather conditions a grower can not always pick his berries at the proper time, but if strawberries are to be shipped by parcel post they should be entirely free from overripe fruit, as two or three overripe berries in each quart will cause considerable damage in such shipments and also will make the entire lot unattractive upon arrival at destination.

Berries which are water-soaked when they are picked or which have grown rapidly after a rain can not be shipped satisfactorily by parcel post. During hot weather, parcel-post shipments of strawberries usually arrive in poor condition as the berries become soft and crushed in transit. In such cases the berries are not attractive and must be used at once to prevent spoilage. The successful use of the parcel post for shipping strawberries is governed largely by weather conditions, and difficulty often results because of frequent rains and high humidity during the strawberry shipping season.

PICKING AND PACKING.

The treatment that is given strawberries in picking and handling in the field, and in packing, has much to do with the damage which occurs when they are shipped. Most growers are forced to employ unskilled laborers and children to pick berries, payment being made on the basis of the quantity picked. Unless considerable supervision is given to such labor, it is likely that berries of nearly all degrees of maturity will be placed in the baskets. When the berries are ripening very rapidly they should be picked every day so that there will be little opportunity for the fruit to become overripe.

During the periods when experimental shipments were made, it was noticed that some pickers placed in the baskets many berries that were picked without the caps. Berries from which the caps have been removed will not ship well, as they soon begin to spoil. Green and overripe berries also are included by careless pickers, especially where payment is based on the quantity rather than on the quality of the fruit picked. Children sometimes replace in baskets the berries which they pick up from overturned boxes. In such instances the berries usually are somewhat bruised and conditions for decay are encouraged. Grass and trash also are picked up with the fruit and their presence gives the berries an unattractive appearance.

Growers who wish to ship berries direct to consumers by parcel post should see that care is exercised in picking and handling the berries in the field in order to prevent the inclusion of both green and overripe berries which detract much from the appearance of a basket of the fruit.

Berries which are to be shipped by parcel post should not be handled after they are picked, and for this reason the supervision of the pickers in the field should be such as to favor the picking and packing of fruit of good marketable quality only.

Some growers permit the pickers to leave berries in the sun until a certain number of quarts have been picked. While a picker should not be required to take his berries to the packing shed too frequently, some method should be used which will get the berries out of the sun soon after they are picked. In carrying the berries from the field to the packing shed, care should be taken that the fruit is not bruised or in any way injured. The packing shed should be convenient to the field and should be well ventilated. The person packing the berries should see that the baskets are well filled as the berries will settle considerably while they are in transit. The baskets should be placed carefully in the crate while both the baskets and dividers should be in the proper place. In order to allow all the ventilation possible, the covers of the crates should not be closed until the berries are to be hauled to the station.

CONTAINERS.

Various kinds and sizes of containers were used in making the experimental shipments of strawberries. Some of the crates that were used are illustrated in figure 2.

Data obtained indicate that a crate which permits ventilation is necessary for shipping berries by parcel post. The crates which gave the best results were made with slatted sides and bottoms, and were provided with racks or dividers to separate each layer of baskets.

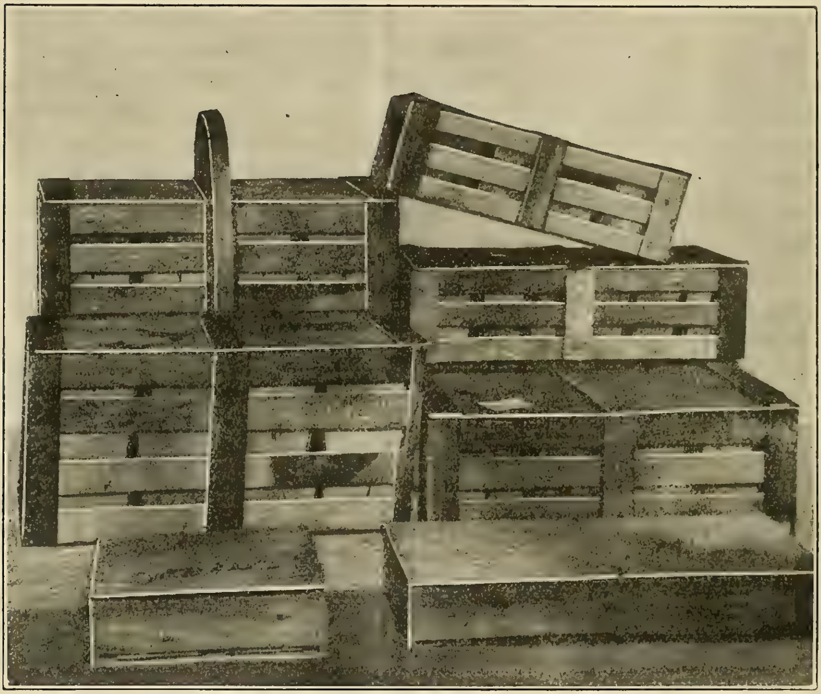

FIG. 2.—Various sizes and styles of crates used in making experimental shipments of berries and cherries.

Figure 3 shows all parts and the construction of a style of crate that gave satisfaction in experimental shipments.

The baskets used in these crates were the standard square berry baskets which are smaller at the bottom than at the top. This construction allows a circulation of air around each basket of fruit. Experiments were made with crates holding pint baskets as well as with those holding quart baskets. In a few instances the berries in the quart baskets arrived in better condition than those in the pint baskets, but in most cases no difference was noticed.

In nearly every shipment the berries in the top layer or tier of baskets were softer and had settled more than the berries in the other layer or layers. In the crates which were used the first season that shipments were made, the top layer of baskets was not held in place as securely as the other layers and it was thought that the damage was caused by the top layer being shaken around more than the other layers. However, in the crates which were used the last two seasons, the berries in the top layer of baskets were softer and settled more than the berries in the other layers of baskets, notwithstanding the fact that the top layer of baskets was held securely in place. As the cover of the crate is solid and rests on the sides and ends of the crate, it seems certain that the damage to the berries in the top layer of baskets was due entirely to the fact that the top layer did not receive as much ventilation as the other layers. In some of the smaller crates which were used, space was provided for only one layer of baskets and in most of the shipments of berries that were received in these crates the berries in each basket were somewhat soft and settled. These facts indicate that ventilation is necessary for success in shipping strawberries by parcel post. No doubt many persons who have been unsuccessful in shipping strawberries by this method have used crates which do not allow ventilation.

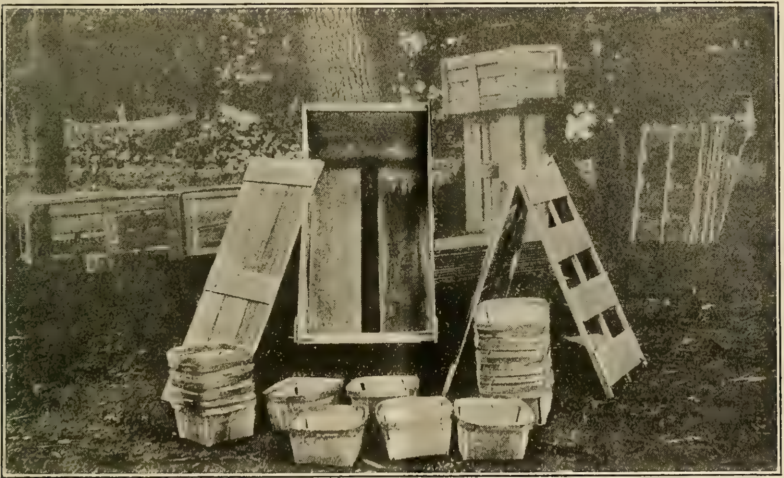

FIG. 3.—Ventilated crate. All parts shown; slatted sides, ends, bottom slats, covers, dividers, and baskets.

Strawberries shipped in crates holding 16 quarts or more arrived in better condition than those shipped in smaller crates. Not only do large crates allow more ventilation than smaller crates, but they are doubtless handled more carefully in the mail. The use of crates holding less than 16 quarts can not be highly recommended for shipping strawberries by parcel post. This factor places a distinct limitation on the use of the parcel post for shipping strawberries, as many growers state that they have difficulty in obtaining customers who wish as many as 16 quarts of strawberries at one time. Persons who wish to ship strawberries by parcel post should endeavor to get customers who will take a crate of berries and divide it among their neighbors.

Growers who send strawberries direct to consumers should always use clean, new crates and baskets in order that a good appearance will be presented. The crates need not be made of heavy material, but should be strong enough to carry the berries safely. A crate with slatted sides and bottoms made of material which does not split easily is the most satisfactory.

MAILING STRAWBERRIES.

A crate of strawberries or any other shipment which is sent by mail should bear the name and address of the sender, preceded by the word "From." This should be written legibly on the cover of the crate in the upper left hand corner. The full name and address of the person to whom the parcel is sent should be written legibly on the cover of the crate or if it is written on a tag, care should be exercised to fasten the tag securely to the crate. If the parcel is sent to a city, complete street address should be given. The crate should be marked "Perishable" so that it will be handled properly in the mail.

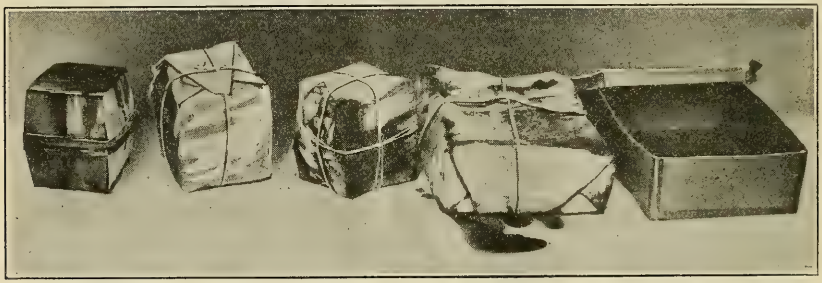

FIG. 4.—Unsatisfactory packages and methods of preparing berries for shipment by parcel post. Such packages do not allow ventilation and also do not comply with the regulations of the Post Office Department.

The regulations of the Post Office Department state that strawberries in parcels weighing less than 20 pounds will not be accepted for mailing unless they are inclosed in an inner cover and strong outer cover of wood, metal, heavy corrugated pasteboard, or other suitable material, and wrapped so that nothing can escape from the package. As previously stated, the results of the experimental shipments made by this bureau prove that berries can not be shipped satisfactorily when packed so that they will not receive ventilation. The packages and methods of wrapping that are illustrated in figure 4 should be avoided in making parcel post shipments.

If berries are sent in parcels weighing less than 20 pounds and are packed in accordance with the regulations of the Post Office Department, absolutely no ventilation is allowed to the berries. Berries shipped in parcels weighing over 20 pounds are transported outside of mail bags, and this permits the use of a crate which allows ventilation. Parcels which weigh over 50 pounds can not be sent by parcel post to points outside of the third postal zone, but within the first, second, and third zones parcels weighing 70 pounds will be accepted for mailing. A 32-quart crate filled with strawberries weighs over 50 pounds if the baskets are filled.

Further information about postal regulations may be secured from any postmaster.

Persons who wish to ship strawberries by parcel post should obtain information relative to mail schedules in order to avoid taking them to the post office too long a time before mail is dispatched. Where it is practicable, berries should be mailed so that they will be transported at night and will arrive in the city in time to be delivered on the first delivery the following morning.

In hauling the berries to the post office a vehicle with good springs should be used so that the berries will not be crushed by jolting. A cover or shelter of some kind should be provided to protect the berries from the sun and dust.

At many post offices and stations, crates of berries receive poor treatment after they are presented for mailing. Facilities for handling large parcels at many post offices and for hauling them to and from trains often are very poor. Mail usually is taken to the depot about one-half hour before the mail train is due and during the berry shipping season trains are often late. While the experimental shipments of strawberries were being made, berries frequently were left in the sun at the depot for nearly an hour.

Whether berries shipped by parcel post will arrive in good condition or not depends also on the manner in which they are handled in the mail cars, at transfer points, and at the post offices to which they are sent. Persons who have been unable to ship strawberries satisfactorily by parcel post should endeavor to ascertain whether the difficulty lies in the picking and packing of the fruit or in the treatment given parcels while in transit.

ECONOMIC CONSIDERATIONS.

In many places crates holding less than 32 quarts can not be obtained, while few persons in cities wish to buy 32 quarts of berries at a time. Some firms which manufacture berry containers carry in stock crates having a capacity of less than 32 quarts and often they will make almost any size crate desired on special order.

A 16-quart ventilated crate, complete with baskets, usually costs from 19 to 25 cents, depending on the location of the grower and the quantity of crates which he buys at one time. The shipping weight of a 16-quart crate of strawberries is from 27 to 31 pounds, and the postage to points within the first and second postal zones (approximately 150 miles) is from 31 to 35 cents. Therefore the cost of the crate and postage for shipping 16 quarts of strawberries is from 50 to 60 cents. The charges for postage will average about 2 cents per quart on a shipment of 16 quarts. For shipments of less than 16 quarts the cost per quart for both the crate and the postage will be relatively higher.

Whether or not a grower will profit by shipping strawberries by parcel post can be decided only by giving due consideration to all of the various factors entering into the proposition. Some of these factors are the cost of marketing by this method and the net returns to be realized as compared with the expense and profits incidental to other methods of marketing, the quantity of berries to be marketed, the location of the shipper with reference to his post office and his market, and the ability of the shipper to develop and maintain a mail-order business.

BLACKBERRIES.

During 1915 and 1916, 34 experimental shipments of blackberries were made by parcel post. Practically all of these shipments were made in crates with a capacity of 16 quarts. The blackberries were shipped an average of 162 miles, and an average of 22 hours elapsed between the time the berries were shipped and the time they were received. During a large part of these two seasons the weather was very unfavorable for shipping berries by parcel post. In a number of instances the berries were too ripe for shipping when they were picked. Seven shipments were received in good condition, 18 in fair condition, and, largely because of delay in delivery, 9 shipments were received in poor condition. The berries in 25 of the shipments were fit to use but in some instances were rather soft.

Most of the shipments in which the berries were received in poor condition were made in unventilated crates. In shipping blackberries by parcel post the use of ventilated crates is recommended, as the berries undoubtedly break down from lack of ventilation in crates made with solid sides. While berries shipped in unventilated containers may be fit for use on arrival at destination, they are usually soft and settled in the baskets and are unattractive in appearance.

If a grower wishes to ship blackberries by parcel post, he should exercise care in picking and packing the berries. Carelessness in picking and handling blackberries sometimes causes more injury to the fruit than does the treatment given while in transit. Success in shipping blackberries is dependent largely on favorable weather conditions and the way in which the fruit is handled in transit.

The shipping weight of a 16-quart crate of blackberries is from 27 to 30 pounds, and the charge for postage to points within the first and second postal zones is from 31 to 34 cents. The cost for crate and postage on a 16-quart crate of blackberries will vary, therefore, from 58 to 64 cents. It may be possible at times to ship more than one kind of berries in a crate such as a combination shipment shown in figure 5.

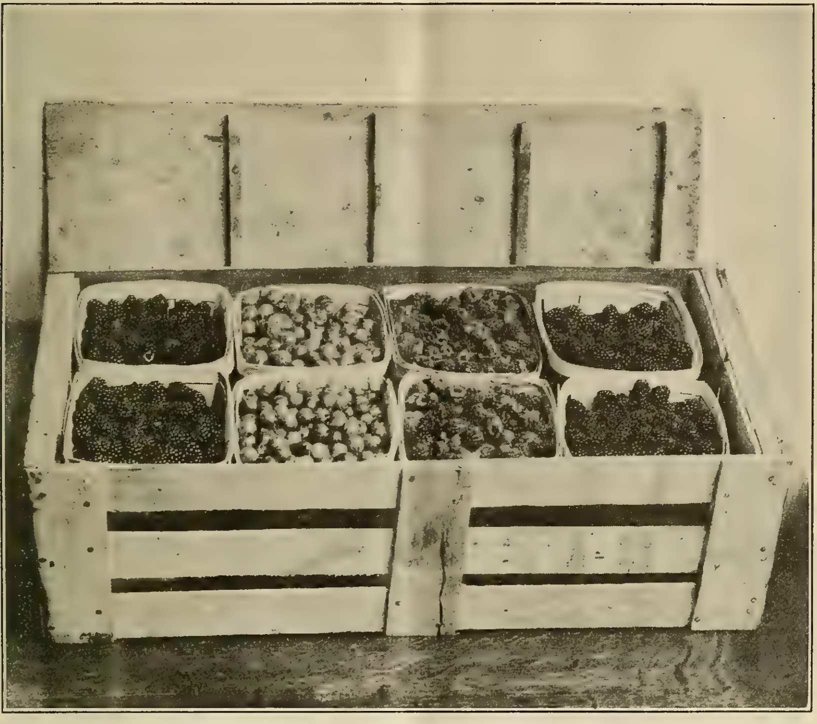

FIG. 5.—Combination shipment of blackberries, raspberries, and gooseberries. Where two or more kinds of berries are available such shipments may be desirable.

Suggestions already made in relation to the shipping of strawberries are applicable to the shipping of blackberries.

BLUEBERRIES OR HUCKLEBERRIES.

Thirteen experimental shipments of huckleberries were made in 1915. In two of these shipments corrugated paper-board boxes with a capacity of 2 quarts were used, while the other shipments were made in ventilated crates with capacities of 8 and 16 quarts. The berries shipped in the corrugated paper-board boxes were received in poor condition, as both the berries and the containers were wet and crushed. The damage to the berries probably was caused by the lack of ventilation.

The berries shipped in ventilated crates were received in good condition, except that in a few instances they were somewhat wet. It was observed in shipping huckleberries that it was difficult to keep the berries from being spilled from the baskets. (See fig. 6.)

Baskets for shipping huckleberries are made with the veneer at the corners of the baskets lapped so that the berries can not escape from the bottom and sides of the basket. As the berries are small and nearly round, however, they roll easily from the top of the baskets unless something is provided as a cover, and such covering together with the lapped corners of the baskets allow little ventilation. A crate of huckleberries in which the baskets are not covered so that the berries can not escape must be transported right side up in order to keep the berries in place. Small parcels of berries often are not carried in this way in the mail and frequently larger crates of berries are placed on end or bottom side up.

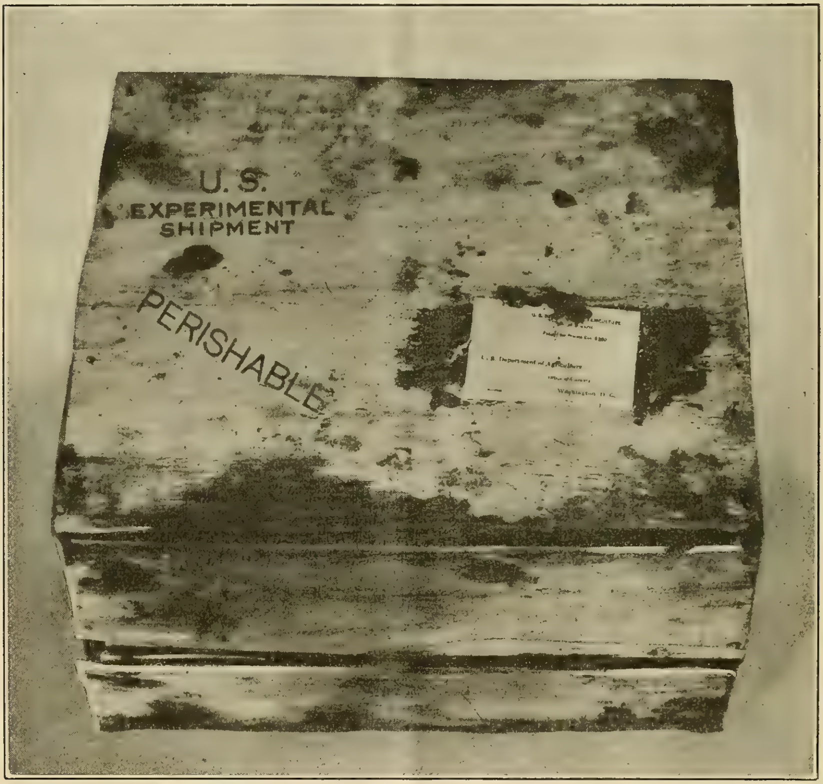

FIG. 6.—Huckleberries shipped by parcel post in an 8-quart ventilated crate. This crate was badly stained by the berries spilled from the baskets in transit.

Care must be exercised in shipping huckleberries by parcel post and unless particular attention is given to the selection of proper containers and the packing of the fruit, failure will result.

RASPBERRIES.

During 1915 and 1916 experimental shipments of raspberries to the number of 74 were made by parcel post. Nine of these shipments were of black raspberries and the others were of red raspberries. The berries were shipped in crates of various sizes and types. Pint baskets were used in most of the crates, although a few shipments were made in crates supplied with quart baskets. The crates in which pint baskets were used varied in capacity from 12 to 32 pints. The experimental shipments of raspberries were made over distances which averaged nearly 200 miles and an average of 18 hours elapsed between the time the berries were shipped and the time they were received.

Few of the shipments of raspberries were received in good condition. A number of shipments were received in fair condition and the berries were fit for use although they were somewhat soft. In most of the shipments the berries were soft and crushed and in many of them the berries were moldy or had become sour.

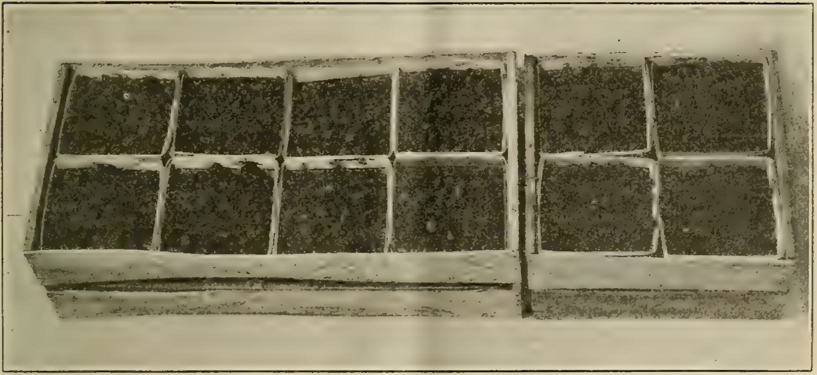

Fig. 7.—Black raspberries shipped by parcel post. One crate contained 16 quarts and the other held 8 quarts. These berries were picked at the proper degree of maturity and were shipped under favorable weather conditions.

It is necessary to use shallow containers of small capacity in the crates used for shipping these berries. Raspberries are of such a delicate texture and are of such a structure that they have a decided tendency to mass together and it is difficult to provide ventilation. The berries should be handled as little as possible after they are picked while crates containing raspberries should be handled very carefully. Parcels sent through the mail must, of necessity, be handled several times and doubtless this causes much damage to raspberries shipped by parcel post.

The cost of shipping raspberries by parcel post is slightly higher than that of shipping strawberries or blackberries because raspberries are shipped in pint baskets. A 32-pint crate complete with baskets costs from 27 to 31 cents. The shipping weight of a 32-pint crate of raspberries is from 31 to 34 pounds and the postage to points within the first and second postal zones is from 35 to 39 cents. Therefore, the cost of a crate and postage for shipping 32 pints of raspberries is from 62 to 70 cents.

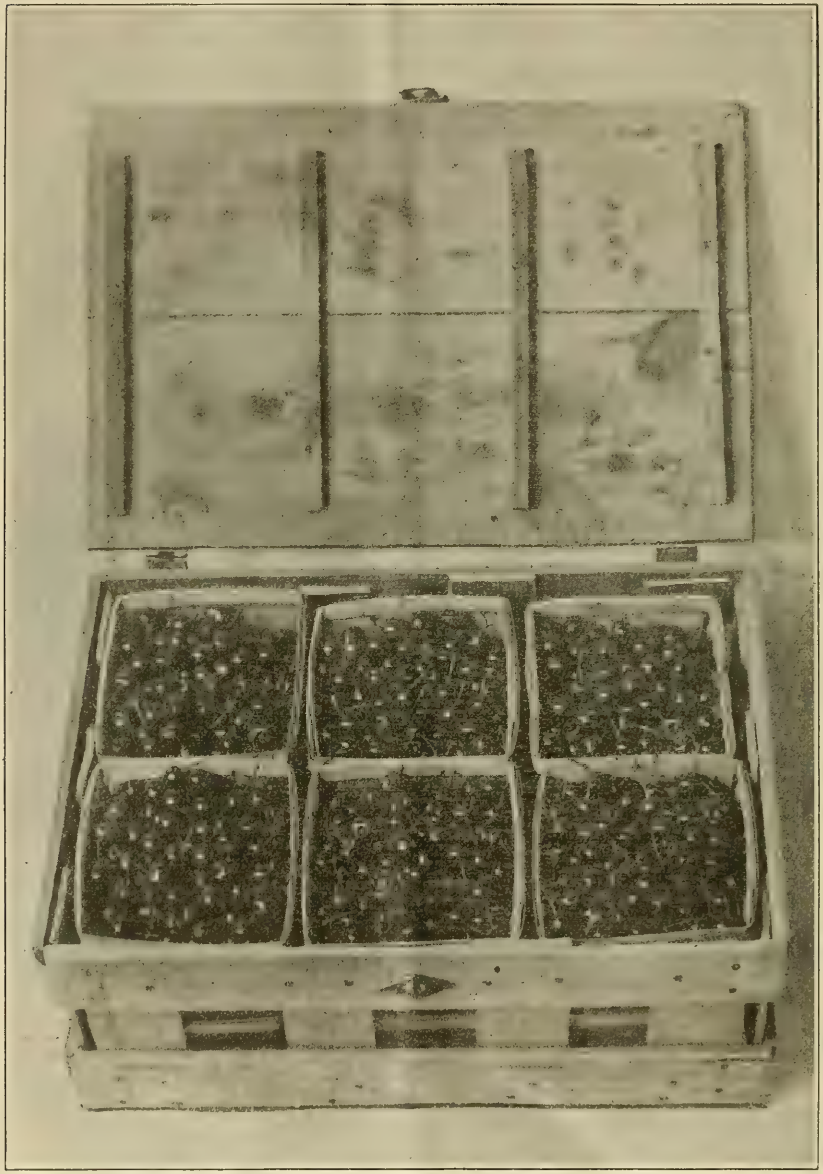

FIG. 8.—Cherries shipped over 100 miles by parcel post. This style crate, holding 12 quarts, is heavier than is necessary for shipments of this quantity of fruit.

The results of the experimental shipments of raspberries indicate that it is not advisable to ship raspberries by parcel post unless the berries are dry and firm when they are picked, are packed properly, are shipped under very favorable weather conditions and are carefully handled in the mail. As illustrated in figure 7 it is possible to ship raspberries satisfactorily by parcel post if all conditions are favorable. However, as a general proposition the use of the parcel post service for shipping raspberries can not be recommended.

CHERRIES.

During 1915, 1916, and 1917 experimental shipments of cherries to the number of 229 were made by parcel post in crates with a capacity of from 4 to 32 quarts. The shipments totaled 3,266 quarts of cherries. An average of 17 hours elapsed between the time the cherries were mailed and the time they were delivered. Practically all of the shipments were made over distances less than 150 miles.

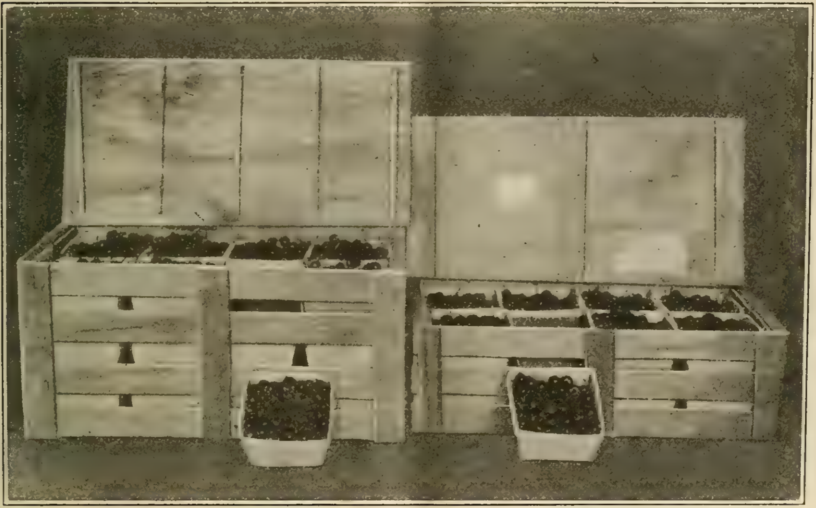

FIG. 9.—Cherries shipped by parcel post. The crate on the left contained 24 quarts and that on the right had a capacity of 16 quarts. Crates of this type usually are satisfactory for shipping cherries by parcel post.

Approximately 75 per cent of the shipments were received in a very satisfactory condition as no damage resulted from the treatment given them while in transit. Three of these shipments are illustrated in Figures 8 and 9.

From 2 to 5 per cent of the cherries in 15 per cent of the shipments were unfit for use, and in 10 per cent of the shipments one-tenth or more of the cherries were damaged when they were received. Nearly all of the cherries that were not received in good condition had been picked carelessly or had become too ripe before they were picked.

In some of the shipments there was included a quart of cherries which had been picked without the stems. In such cases, although there was scarcely any damage to the cherries picked with the stems, from 25 to 90 per cent of the cherries picked without the stems were damaged. A comparison of cherries shipped with stems and without stems is shown in figure 10.

Cherries from which the stems have been removed begin to decay quickly, as the removal of the stem causes a wound in the flesh of the fruit, which allows the entrance of fungi, which cause cherries to mold or decay. Growers should exercise care in picking and packing cherries so that the skin of the fruit will be unbroken, otherwise they will reach the consumer in poor condition.

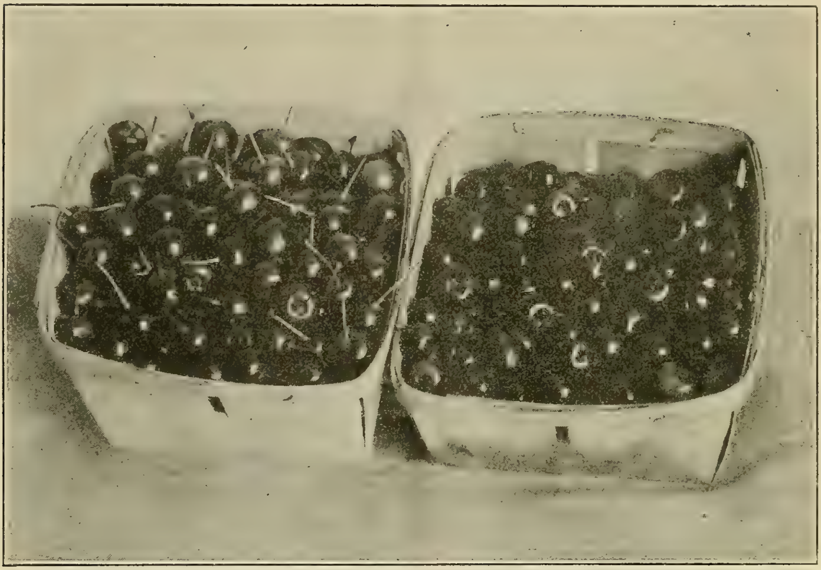

FIG. 10.—Cherries shipped with stems and without stems. The fruit in the basket on the left was picked and shipped with the stems and was received in good condition. That in the basket on the right was shipped with the stems removed. About 90 per cent of the cherries showed signs of decay where the flesh of the fruit had been injured by the removal of the stems.

Cherries that are to be shipped by parcel post should be picked by grasping the stem and not the cherry, and many cherries should not be held in the hand at one time, as this will crush or bruise the fruit and allow the entrance of fungi, which will cause decay or mold. Care should be exercised in emptying the cherries from the vessel in which they are picked into the shipping container so as to avoid injury to the fruit.

For shipping cherries by parcel post, a ventilated crate such as is recommended for shipping strawberries by parcel post, should be used. The shipping weight of cherries is about the same as that of strawberries, so that the cost of shipping them by parcel post is approximately the same as that of strawberries.

The results of the experimental shipments of cherries show it is practicable from a physical standpoint to ship this fruit by parcel post if it is picked in the proper condition and if care is exercised in picking, packing, and mailing. Whether or not it is practicable from an economic standpoint, depends upon the particular conditions in each case. The grower should compare the net returns that can be obtained by shipping cherries by parcel post with the net returns that can be realized by marketing through the regular channels, and then use the method by which he can obtain the greatest net profit.

OBTAINING AND RETAINING CUSTOMERS.

A grower who desires to develop a market for berries or cherries to be shipped by parcel post must, of course, secure customers and carry on the necessary business transactions. Many producers have friends and relatives in cities who would be glad to receive fruit direct from the grower. By securing friends or relatives as customers, a grower should be able to secure additional customers through their recommendations. In order to retain customers, produce of high quality and of good appearance must be furnished and the shipper must be prompt and businesslike in all his transactions.

Further information relative to securing customers and maintaining business relations will be found in Farmers' Bulletin No. 922, Parcel Post Business Methods.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 689

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER. July 30, 1918

THE SOUTHERN GREEN PLANT-BUG.

By Thos. H. Jones,

Entomological Assistant, Truck-Crop Insect Investigations.

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INTRODUCTION.

In the extreme southern portion of the United States, particularly in those States bordering the Gulf of Mexico, a large pentatomid bug, *Nezara viridula* L., is a serious pest on cultivated plants. Important vegetable and truck crops are subject to injury and it is as an enemy of such crops that the species is considered in this article. The investigations upon which the article is based have been carried on principally at Baton Rouge, La.[1]

Nezara viridula is here given the name of "the Southern green plant-bug." The word "Southern" is proposed to distinguish the species from the closely related *Nezara hilaris* Say. While the latter is also a pest on cultivated plants, and approaches *viridula* in color, its range extends farther north in the United States than does that of *viridula*.

NATURE OF DAMAGE.

Both adults and nymphs feed by inserting their beaks into the plant tissue and extracting the plant juices, minute spots marking the points where the beak has punctured. The growing shoots of plants, and especially developing fruit, are preferred as feeding places. Attacked shoots usually wither and are either retarded in their growth or, in cases of severe infestation, die. Such damage has been noted on Irish potato and sweet potato.

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[1] The writer wishes to acknowledge the cooperation, in this investigation, of Messrs. C. E. Smith and J. L. E. Lauderdale, while members of the Bureau of Entomology. The drawings of figures 4, 5, 9, 12, and 13 and the photographs (figs. 1-3 and 6-8) have been prepared by Mr. W. M. Dovener of the Bureau of Entomology.

In the case of immature fruit the tissue around the point where the beak has been inserted does not develop normally and these points sometimes become centers of callous growth. The growth of developing fruit is retarded when injured in this manner and the fruit often withers and drops from the plant. Injured tomatoes, although small and distorted, sometimes assume a yellow color.

During 1917 injury by the nymphs to tomatoes and beans was demonstrated by confining nymphs with tomato fruits and growing beans. In the case of tomato a number of small green fruits growing in the field were closely covered with cheesecloth. In some of these covers nymphs were placed while other fruit was left to serve as checks. Examination later showed that those fruits with which nymphs had been confined had not developed to the same extent as did the check fruit. In some cases the fruits upon which nymphs had fed withered later and dropped from the stem. (See fig. 1.)

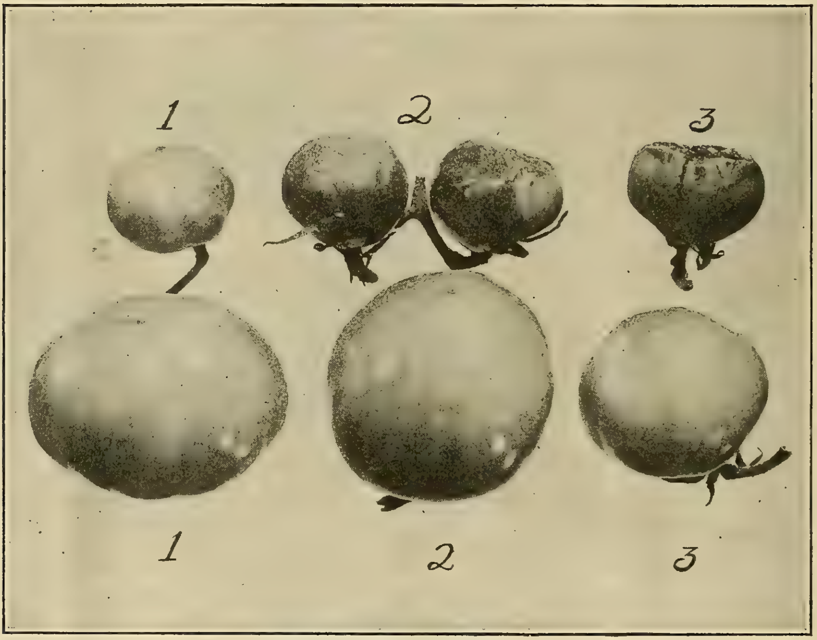

FIG. 1.—Injury to tomato fruit by nymphs of the Southern green plant-bug (*Nezara viridula*): Injured fruit above, normal fruit below. Developing fruit was covered with cheesecloth sacks in which nymphs were confined. Fruit bearing same number was approximately same size when inclosed in sacks.

Beans growing in flowerpots were placed under covers. Nymphs were confined with some, while other plants were used as checks. No fruit developed on those plants upon which nymphs were allowed to feed. While the amount of fruit that developed on the check plants was not as great as it would have been under natural field conditions, the effect of the feeding of the nymphs was apparent when plants receiving the two treatments were compared. (See fig. 2.)

During 1916 an unusual type of injury to cauliflower was reported from Breaux Bridge in St. Martin Parish and from Terrebonne Parish, La. This was apparently due to the feeding of both adults and nymphs of the Southern green plant-bug. They were numerous at and about the point where the leaf stems are attached to the main stalk of the plant. The stems became discolored and the leaves dropped prematurely.

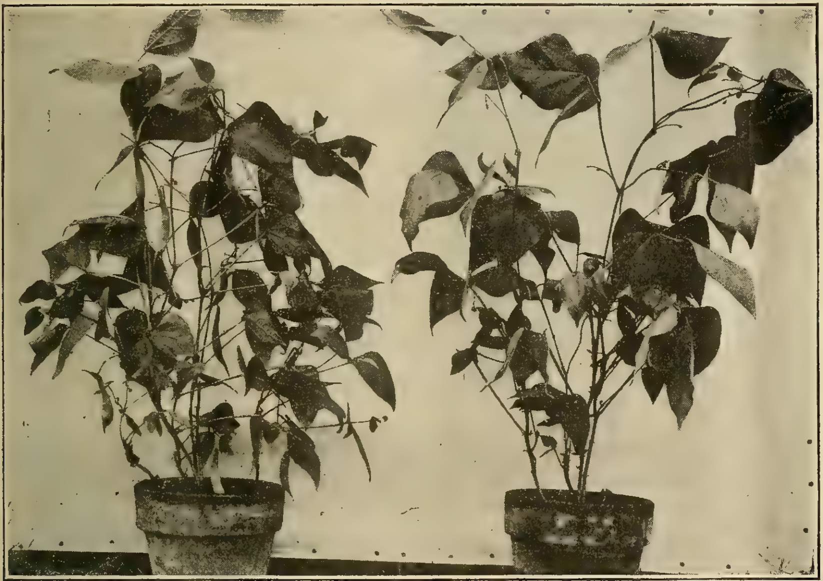

FIG. 2.—Injury to beans by nymphs of Southern green plant-bug. Beans growing in flowerpots were placed under wire cages. No pods developed on plants at right, with which nymphs were confined.

DESCRIPTION OF STAGES.

THE ADULT.

The adult (fig. 3) when viewed from above has the characteristic form of the family Pentatomidæ, which may be described as shield-shaped. The dorsal surface of the body is slightly, and the ventral surface strongly, convex.

In living specimens the body as well as parts of the appendages are usually light green, the dorsal surface being somewhat darker than is the ventral surface. Exceptions to this may be found in the case of adults collected during the cooler months of the year. Such individuals are darker in color, perhaps because of the lower temperatures to which they are subjected, the light green in certain individuals being replaced by purple. Mounted specimens are usually dull green.

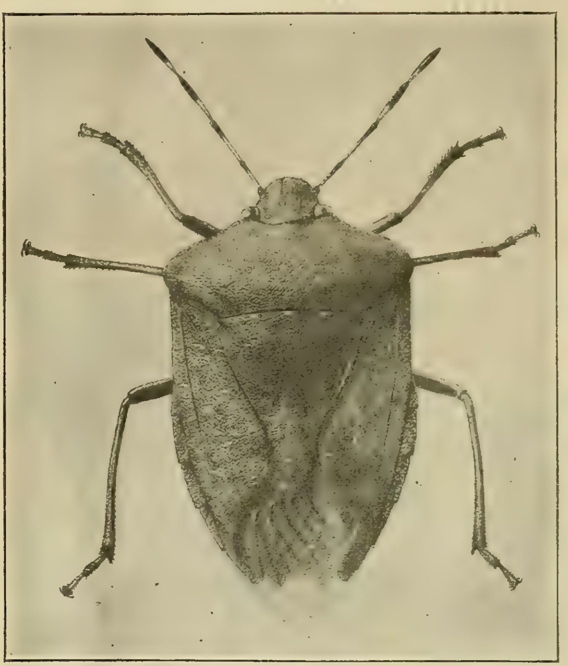

FIG. 3.—Southern green plant-bug (*Nezara viridula*): Adult. Enlarged about 4 diameters.

There is considerable variation in size, the average female being somewhat larger than is the average male. The sexes are differentiated by the appearance of the last abdominal segment, especially by the presence of a notch in the margin at the posterior end of the abdomen of the male (fig. 4.). This notch is not present on the female (fig. 5). A technical description follows.

Subovate, dorsal surface slightly convex, ventral surface strongly so. Color usually green, sometimes tinged with purple. Head somewhat prolonged, angular, tylus equalling cheeks. Eyes very dark red or black, ocelli appearing as tiny beads of amber. Antenna five-jointed; in comparative length the order is as follows: First, second, fifth, third, and fourth, the fourth being the longest. In green specimens the distal end of third antennal segment, and at least the distal half of fourth and fifth, is dark, of a red or brown color. Labrum dark red or brown, a dark line extending from the end of the labrum to dark tip of beak. Sides of pronotum nearly rectilinear. Three or five white points at base of scutellum along edge of pronotum. Black dot at each basal angle of scutellum. Distal end of tibia, and the tarsi, brownish. Small black dots along sides of abdomen at posterior tip of each segment. In purplish specimens coloration not so apparent. When wings are folded, entire surface of body, except membranous portion of wings, roughened by numerous punctures, especially dense on dorsal surface. Osteolar canal or orifice short, rather broad, truncated at apex, and not extending more than half way to lateral margin of metapleura.

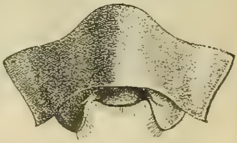

FIG. 4.—Southern green plant-bug: Ventral view of tip of abdomen of male. Greatly enlarged.

From center of base of head to tip of abdomen 10 males average 12.1 mm., ranging from 11 to 13.5 mm. Average width at shoulders 7.85 mm., ranging from 7 to 8.5 mm. Average length of 10 females 13.15 mm., ranging from 12 to 15.5 mm. Average width at shoulders 8.3 mm., ranging from 7.5 to 9.5 mm. Average length of head about 2 mm.

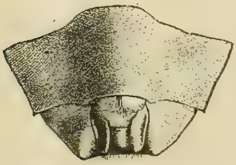

FIG 5.—Southern green plant-bug: Ventral view of tip of abdomen of female. Greatly enlarged.

COMPARISON WITH OTHER SPECIES OF NEZARA.

Four species, namely, *viridula* L., *pennsylvanica* DeG., *hilaris* Say, and *marginata* P. B., usually have been considered as belonging to the genus Nezara.[1] Whether considered of sufficient importance to be a generic character, or only a specific one, the difference in the shape of the orifice (osteolar canal) is the most satisfactory character for separating *viridula* from the other species. In *viridula* (fig. 6) the orifice is short, rather broad, truncated at the apex, and does not extend more than half way to the lateral margin of the metapleura. In the other three species (see fig. 7) it is long and curved, becoming gradually evanescent, and extends almost to the posterior lateral angle of the mesopleura.[2]

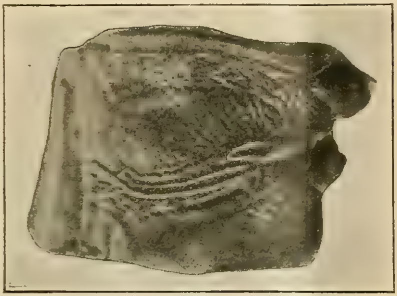

FIG. 6.—*Nezara viridula:* Portion of ventral surface of mesothorax and metathorax, showing the orifice or osteolar canal. Coxæ of legs of second and third pairs at right. Greatly enlarged.

THE EGG.

The egg (figs. 8 and 9) is cylindrical, rounded at the lower end and flattened on top. On the top are the short, club-shaped chorial processes arranged in a circle and attached to the egg between the cap and the outer edge by their smaller ends. Their distal ends are bent toward the center of the cap. The writer has found the number of chorial processes on an egg to range from 28 to 32. Whitmarsh (13),[3] in his description of the stages of *Nezara hilaris*, states that there are as many as 65 of these processes on the egg of that species.

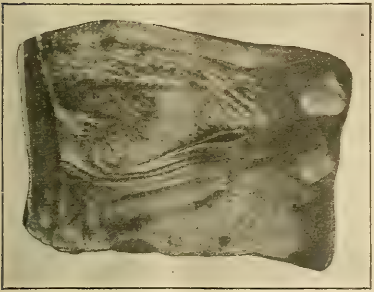

FIG. 7.—*Nezara hilaris:* Portion of ventral surface of mesothorax and metathorax, showing the orifice or osteolar canal. Coxæ of legs of second and third pairs at right. Greatly enlarged.

The surface of the egg is roughened, with traces of hexagonal markings. A number of eggs that the writer has measured gave an average height of 1.24 mm. and an average diameter of 0.85 mm.

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[1] Some writers include *viridula* only under this genus, placing the other three species under the genus Acrosternum of Fieber.

[2] Some authorities mention other characters by which *viridula* may be distinguished, but the writer, finding some of these inconstant, considers it advisable to mention only the difference in the shape of the orifice.

[3] Numbers in parentheses refer to "Literature cited," p. 26.

When first deposited, eggs that have been kept under observation were of a cream color. Later they became salmon color and just before hatching the crimson markings of the inclosed nymphs were visible through the shell, a somewhat triangular area on the head being especially conspicuous.

NYMPH STAGES.

There is a marked variation in the coloration of different nymphs in the same period of growth and individuals vary considerably in coloration from day to day. The writer has observed a marked difference in coloration of different individuals after the third and fourth molts, as indicated by Morrill (7) in his figures of nymphs in the fifth instar. There are found in the fourth and fifth instars both light and dark nymphs, as well as others of intermediate coloration. In the case of numerous individuals that have been under observation it has been found that in the fourth instar the percentage of nymphs of the light and dark types—if such they may be called—is about the same. Nymphs in the fifth instar belong for the most part to the light type.

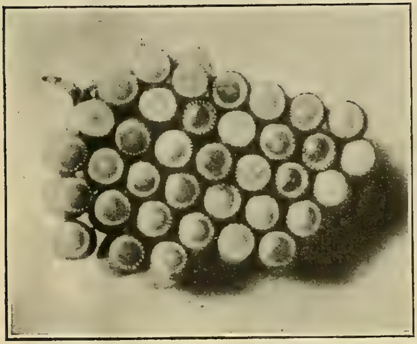

FIG. 8.—Southern green plant-bug: Egg-cluster, viewed from above. Enlarged about 6 diameters.

In the following descriptions the color notes should not be considered as having too great significance. Up to and including the third instar these notes refer, in so far as coloration is concerned, to normal or average nymphs, during the summer months. For the nymphs in the fourth and fifth instars two forms are described. One represents the darkest and the other the lightest form that the writer has found.

While the writer has not had the opportunity of examining the nymph stages of *Nezara hilaris*, the species with which *viridula* is most likely to be confused in the United States, it is evident from Whitmarsh's (13) descriptions and figures, especially with regard to the coloration and markings on the dorsal surface of the adbomen, that the nymphs of *hilaris* and *viridula* are quite distinct. In *viridula* the number and arrangement of the light-colored spots on the dorsal surface of the abdomen of nymphs in the second to fifth instars, inclusive, are very constant (although some of them are not apparent in the fifth instar, as they are covered by the wing pads), and serve to distinguish the nymphs from those of *hilaris*, in which these spots are not present. (Figs. 10 and 11.)

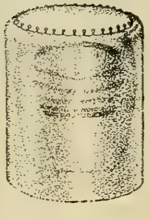

FIG. 9.—Egg of Southern green plant-bug, lateral view, showing embryo within. Highly magnified.

Dorsally the surface of the head and thorax of all stages is roughened by punctures and wrinkles. The surface of the abdomen is smoother, the punctures and wrinkles present being largely confined to areas around the glands and along the sides. Short setæ are scattered over the surface of the body and appendages. The margins of the thorax, which in the instars succeeding the first are serrated, are most prominent in the third and fourth instars.

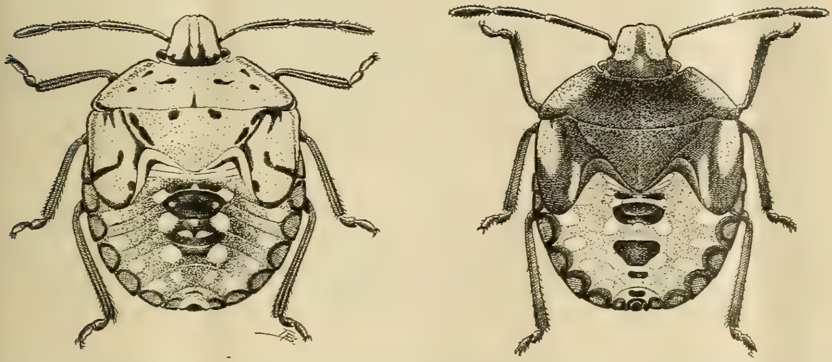

FIG. 10.—Southern green plant-bug (*Nezara viridula*): Nymph, fifth instar; light and dark types Enlarged about 4 diameters. (Morrill.)

Immediately after molting the abdomen of the nymph is quite flat dorso-ventrally but it gradually becomes thicker, until just before the new molt it is turgid and glistening. The nymph increases in size from the beginning to the end of any instar and the length and width is also increased through molting.

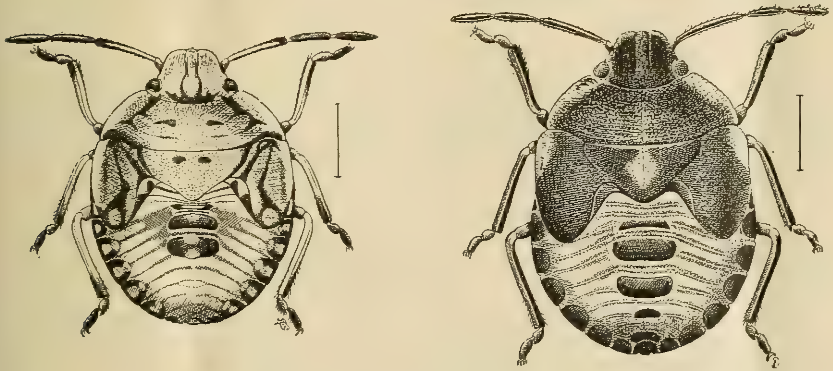

FIG. 11.—The green plant-bug (*Nezara hilaris*): Nymph, fifth instar; light and dark types. Enlarged about 4 diameters. (Morrill.)

Especially in the last two instars there is considerable variation in the size of different individuals in either stage even just after or before molting. This, of course, would be expected from the variation in size of the adults.

In molting the skin splits down the median line of the thorax and at the juncture of the head and thorax on the dorsal surface. Through this opening the nymph gradually works its way, leaving the entire covering of the body behind.

FIRST-STAGE NYMPH.

Ovate, strongly convex above, less so below. Body and appendages with short, scattered setæ. Antennæ, beak, and legs long and stout. Antenna four-jointed; first joint shortest, second and third of about equal length, fourth longest, largest at middle and approaching point at tip.[1] Four-jointed beak reaching beyond base of abdomen. Eyes prominent. Claws simple, two in number, each with pulvillus. Divisions of body and segments of thorax, and to less extent segments of abdomen, marked by indentations along edge.

As the nymphs issue from the eggs they are colored as follows: Eyes and a triangular area on top of head, one edge extending from lower point of one eye to lower point of other eye, crimson; remainder of head yellowish white. Thorax and abdomen golden yellow except for traces of transverse crimson lines which, between thorax and abdomen, form a transverse band. Antennæ, beak, and legs without color, nearly transparent.

Until the time of the first molt, when the nymphs attain a length of about 1.6 mm. and a width of 1.1 mm., they become gradually darker.

The following notes refer to their coloration just before molting:

Dorsal surface.

Head: Eyes deep red. Triangular area on head crimson or brown. At least area at base light yellow. Rest of head sometimes brown or in part yellow.

Thorax: Central portion of prothorax and mesothorax light yellow, the sides and rear of this area sometimes tinged with red. Sides of prothorax and mesothorax reddish brown or brown, with yellow sometimes present along edge. Metathorax reddish brown or brown.

Abdomen: Usually darker than head and thorax. For the most part dark brown, sometimes almost black. White spot on either side near base. Three glands, the anterior one being much narrower than the other two, reddish brown with cream-colored spot behind and to either side of last two. Somewhat semicircular, usually yellowish spot on either side of each segment, its straight edge along edge.

Ventral surface.

Head: Light yellow tinged with red. Antennæ light yellow with last segment somewhat dusky at tip and with crimson areas on joints near and at junctures. Beak light yellow with dusky tip.

Thorax: Light yellow tinged with red. Legs of same color with last segment of tarsi somewhat dusky.

Abdomen: Darker than head and thorax, having dusky tinge, especially a band down either side extending from edge about half way to median line, containing along the edge yellow semicircular spots corresponding to those found on dorsal surface.

Sometimes the whole under surface is dusky and the coloration not as distinct as above indicated.

SECOND-STAGE NYMPH.

Shape and relative length of segments of antennæ and beak much as in first stage Sometimes almost entirely black after molting.

The following color notes refer to mature individuals:

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[1] See Table I, giving lengths of antennal segments, p. 11.

Dorsal surface.

Head: Black.

Thorax: Black except for four yellow spots usually present, one near entire outer edge of prothorax and two, similarly located, on mesothorax.

Abdomen: Dark reddish. Tubercles black. Minute light spots sometimes present on median line. When present one is usually found between first and second and one between second and third tubercles. Four light areas, usually white, across base to form what approaches a band. Row of five light dots on either side of median line, the first and second very small and close together. Row of six light spots along either side of abdomen, the posterior one smallest and sometimes not apparent. All light spots are either white or light yellow, those over the central portion of the abdomen being usually yellow. Row of eight black semicircular spots along either edge of abdomen, one on a segment, their straight edges on line where dorsal and ventral surfaces of abdomen meet. Tip of abdomen black.

Ventral surface.

Head: Black. Antennæ and beak black, except for red areas between second and third and third and fourth antennal joints.

Thorax: Black except for yellow spots that may be present on prothorax and mesothorax, corresponding to those on dorsal surface, and reddish area between coxæ. Legs black.

Abdomen Reddish with row of five black spots extending from tip up median line and row of black spots along edge, corresponding to those on dorsal surface. Tip black.

About to molt they measure approximately 3 mm. in length and 2 mm. in width, being widest across the abdomen.

THIRD-STAGE NYMPH.

Shape, coloration, and general appearance same as in second instar, though black may sometimes be replaced by olive green.

When mature it measures about 3.6 mm. in length and 2.6 mm. in width across the abdomen.

FOURTH-STAGE NYMPH.

Shape as in preceding stages. The second segment of the antenna now longest. In this instar occur what may be termed light and dark forms as well as individuals of intermediate coloration. The light and dark forms are described below. When mature the nymph measures approximately 6.2 mm. in length and 4.7 mm. in width.

Light form, dorsal surface.

Head: Pale green with black border and black line on either side of tylus where it joins jugum. These lines extend to middle of base of head where they join small black area. Eyes black.

Thorax: Pale green with few scattered black dots and other black markings. Sides bordered with black and with orange-colored area near edge of prothorax and one of same color near edge of mesothorax.

Abdomen: Darker green than head and thorax. Darkest around glands, last two of which are salmon colored. Four white areas along base of abdomen nearly joined to form what approaches a band across base. Two small white dots on median line. one between first and second and one between second and third glands. Row of five white dots on either side of median line, diverging anteriorly and converging posteriorly. Row of six white dots, the posterior one much smaller than others, along either side of abdomen just inside connexivum. On connexivum six black-bordered, salmon-colored dots.

Ventral surface.

Head: Pale green with yellowish tinge anteriorly. Sides and front bordered with black. First joint of antenna for most part light green, others fuscous. Labrum fuscous, the rest of base of beak light green. Last two segments of beak fuscous.

Thorax: Pale green with few scattered black dots and lines. Sides bordered with black and with orange-colored area just inside border. Femora light green. Tibiæ and tarsi dusky to fuscous.

Abdomen: Pale yellowish green. Sides and posterior end bordered with black, with salmon-tinged band just inside border. Spiracles black.

Dark form, dorsal surface.

Head: Dark brown, nearly black, sometimes with jugum yellow.

Thorax: Dark brown, nearly black, except for yellow area near edge of prothorax and one near edge of mesothorax.

Abdomen: Dark brown, nearly black. Last two segments lighter than others White markings as in light form. Color of glands same as rest of ground color. Salmon-colored areas along connexivum absent.

Ventral surface.

Head: Greenish black. Beak and antennæ of same color.

Thorax: Greenish black except for yellowish areas near edge of prothorax and mesothorax and light, whitish band down median line under beak. Legs greenish black.

Abdomen: Light yellow tinged with red and with greenish-black border at sides and posterior end. Row of five greenish black spots along median line. Spiracles black.

FIFTH-STAGE NYMPH.

Shape much as in preceding stages, but development of wing pads now quite pronounced and basal portion of abdomen in part covered by them. Length, when mature, about 10 mm., width about 7 mm.

Light form, dorsal surface.

Head: Pale green with black border and a black area at base on either side of median line. Eyes for most part black.

Thorax and wing-pads: Pale green with black border on sides and with few scattered black dots and other black markings. A narrow orange-colored band just inside black border, more pronounced on prothorax.

Abdomen: Pale yellowish green with black area about rose-colored glands. Yellowish-white, rounded spots located as follows: Two small ones on median line, one between first and second and one between second and third glands; row of five on either side, just outside median line, the third and fourth largest; row of five on either side near connexivum, the first sometimes covered by wing-pads. On connexivum, at either side of each segment, a rose-colored, black-bordered, somewhat semicircular area, its less curved border outward. Near posterior end of abdomen these areas not well defined.

Ventral surface.

Much as in light form of fourth-stage nymph except that band just inside black border of abdomen is rose colored.

Dark form, dorsal surface.

Head: Juga chrome orange with black border on outside edge. Rest of head and eyes dark brown, nearly black.

Thorax: For most part dark brown, nearly black. Black-bordered, orange-colored areas, one near both outside edges of prothorax and one near outside edge of both primary wing-pads. Yellowish area along inside edge of both primary wing-pads.

Abdomen: Dark brown, almost black.[1] At base a yellowish-white area on either side of median line. Other yellowish-white spots and rose-colored areas on connexivum as in light form.

Ventral surface.

Head: Olive green with black markings. Beak and antennæ olive green to black, lightest near base.

Thorax: Olive green with black markings except for chrome-orange areas near edge of prothorax and mesothorax. Legs olive green near base, becoming gradually darker to black tarsi.

Abdomen: Light yellow tinged with red and with black-bordered, rose-colored areas on connexivum corresponding to those on dorsal surface. Row of four greenish-black spots along median line. Spiracles black.

COMPARATIVE LENGTHS OF ANTENNAL SEGMENTS OF NYMPHS AND ADULT.

While the measurements given in the following table are taken from single individuals only, they indicate the comparative lengths of the segments in any one stage. It will be noted that the antenna of the nymph is made up of four segments while that of the adult is composed of five. In this connection it may be stated that the writer has seen an abnormal adult with one antenna composed of four segments and the other of five.

Up to and including the third instar the fourth segment of the antenna is longest. In the fourth and fifth instars the second segment is longest, while in the case of the adult the last three segments are of about equal length, any one being longer than either the first or the second segment.

TABLE I.—*Lengths of segments of antennæ of nymphs and adults of Nezara viridula.*

Stage.	First segment.	Second segment.	Third segment.	Fourth segment.	Fifth. segment.
	Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*
First-instar nymph	0.14	0.19	0.18	0.37	....
Second-instar nymph	.15	.40	.33	.53	....
Third-instar nymph	.18	.60	.50	.67	....
Fourth-instar nymph	.29	1.17	.88	1.07	....
Fifth-instar nymph	.44	1.71	1.22	1.27	....
Adult	.53	1.07	1.66	1.76	1.56

DISTRIBUTION.

Bueno (9) states that *Nezara viridula* is recorded "from the whole of Europe except the extreme north, Asia, Africa, Malaysia, Australia, New Zealand, South America, at least in the north, Central America, and enters into the United States at the south, being found in Texas and Florida." Specimens have been seen from Cuba, Porto Rico, and St. Croix (U. S. Virgin Islands) in the Lesser Antilles.

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[1] In individuals of this form examined by the writer the general color of the dorsal surface of the abdomen is much darker than Morrill's (7) figure would indicate.

In the United States (fig. 12) its range covers the extreme southern portion, although at times it occurs outside this area. In the files of the Bureau of Entomology there are records of its injurious occurrence in South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas. This would indicate that the species is most numerous in the southern portion of the Cotton Belt.

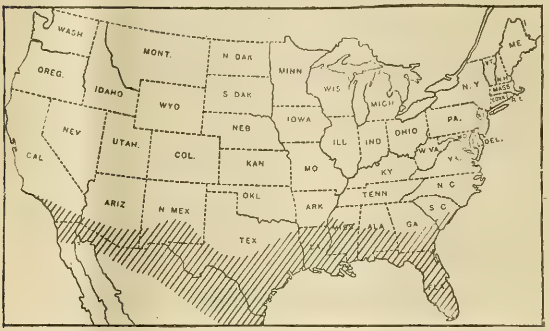

FIG. 12.—Map showing distribution of the Southern green plant-bug in the United States. Shaded areas indicates probable distribution.

From what has been observed in regard to the distribution of this species, it is evident that it is of foreign origin and, like many others of our principal pests, was introduced into this country many years ago. It is also obvious that it would be impossible even to hazard a conjecture as to the source from which it obtained a foothold in the southern United States.

REVIEW OF LITERATURE.

The species was first described as *Cimex viridulus* by Linnaeus (1) in 1758 from specimens from India and, according to Banks (6), it has been described since then under several other names by various authors. Van Duzee (5), Banks (6), and Barber (10) have mentioned areas and localities where it occurs and Van Duzee (5) and Parshley (11) have given characters by which it can be separated from closely related species.

Short notes regarding *Nezara viridula* were published in Insect Life in 1889 (2) and 1893 (3, 4). The notes published in 1893 relate to specimens sent to Washington by correspondents in Plaquemines Parish, La., and Altoona, Fla.

In 1910 Morrill (7) included a short account of the species in Bulletin 86 of the Bureau of Entomology. He mentioned the species as occurring on cotton, potato, and turnip, in Florida, Louisiana, and Texas, and gave figures of the light and dark types of nymphs in the fifth instar.

In 1912 Bueno (9) recorded the finding of the species in a greenhouse in Brooklyn, N. Y., and stated that he believed it to have been introduced from Europe or Florida, though he saw no reason why it could not establish itself in the latitude of Brooklyn inasmuch as it occurred in Germany and Russia. A short description was included and a number of food plants listed.

Froggatt (12), in 1916, recorded it as injuring tomato, French bean, and potato in New South Wales, and stated that it had appeared in the neighborhood of Sydney about five years previous to that date.

It was mentioned by Watson (14), in 1917, as an enemy of various crops in Florida, being treated especially as an enemy of truck and garden crops. Hand collecting was referred to as a satisfactory method of control to be practiced in the garden.

UNPUBLISHED RECORDS.

Among the records in the files of the Truck-Crop Insect Investigations, Bureau of Entomology, there are several notes referring to injury by the southern green plant-bug. Specimens were taken at the time the notes were made and these have been seen by the writer.

Mr. W. R. Beattie collected specimens at Mount Pleasant, S. C., on September 23, 1907, from tomato and stated that "in numerous instances" he "found as many as 5 to 20 working on a single fruit." On October 24 of the same year Mr. H. M. Russell reported severe injury to kumquats and Satsuma oranges in a grove of 1,000 trees at St. Leo, Fla., the insects apparently having migrated to the grove from neighboring cowpeas after these had died. The owner of the grove estimated that because of the injury he had lost all of his Satsuma fruit and 250 boxes of kumquats. The inside of the injured fruit was dry and pithy.

In a note from Brownsville, Tex., dated May 25, 1909, Messrs. D. K. McMillan and H. O. Marsh stated that these bugs were "very abundant during the fall and early winter on eggplant, tomato, okra, cabbage, and corn."

On October 20, 1917, Mr. M. H. Carter, of Troy, Ala., sent adults taken from cowpeas and wrote, "they have caused thousands of dollars damage in south Alabama this year by destroying the field-pea crop."

Mr. H. K. Laramore wrote on November 15, 1917, sending specimens collected at Jacksonville, Tex., on turnip and rutabaga, that the species was very common, doing "a great deal of damage to crucifers especially" and "I am told it is out of the question for them to attempt to raise late cowpeas in Cherokee County."

In the office records are included also other notes which, though unaccompanied by specimens, probably refer to this species. During November, 1911, the American Sumatra Tobacco Co., of Quincy, Fla., wrote regarding injury that "the loss attributable to them can be counted into thousands of dollars." In the case of tobacco it was stated that "wherever they sting a leaf it wilts the same and the leaf becomes absolutely worthless." Injury to velvet beans was also referred to.

Writing from Winnfield, La., on December 8, 1914, Mr. C. P. Seab stated that "it is this bug which attacks the lima and string bean as well as the cowpea. The farmers tell me it is almost impossible to have any kind of beans or peas on account of this bug."

February 2, 1917, Mr. John A. Creel wrote from Clapton, Ala., regarding "green bugs" that "attack peas of all varieties, velvet beans, peanuts, sugar cane, squash, okra, butter beans, etc.," and stated that "they attack any kind of grain or vegetable when in the green stage. The vegetable or grain will, after being punctured, become hard and dry, and good for nothing."

FOOD PLANTS.

Other writers have recorded *Nezara viridula* as feeding on beans, cotton, cowpea, *Gynandropsis pentaphylla*, hackberry, okra, maize, mulberry, orange, peas, pepper, potato, rice, sugar cane, sunflower, sweet potato, tomato, and turnip. We have taken it on a number of these plants and, in addition, on Brussels sprouts, cauliflower, collards, eggplant, globe artichoke, mustard, and radish.

While little damage is recorded to some of the plants mentioned and while it probably does not breed on all of them, it is a quite general feeder. Watson (14) states that it "attacks nearly all garden plants." Among vegetables the writer has found that serious injury is usually to tomato, bean, Irish potato, sweet potato, and okra. In the late fall and early winter the various stages are often abundant on mustard and turnip. They have also been observed congregated on the remaining green portions of okra plants after frost. It appears that legumes are favored as food plants. Farmers sometimes complain that the bugs greatly decrease the yield of seed of cowpeas by injuring the developing pods. Other writers mention the species as a pest on cotton and orange, and the records in the Bureau of Entomology, mentioned above, indicate that it feeds also on cabbage, corn, peanut, squash, tobacco, and velvet bean.

SEASONAL HISTORY AND HABITS.

HABITS OF THE ADULT.

The adults from the last generation of nymphs, some of which may be found feeding at Baton Rouge until late fall and early winter, often congregated on mustard and turnip, usually seek hibernating quarters. Rosenfeld (8) lists them among the insects taken from Spanish moss in Louisiana during December and January. Mr. O. W. Rosewall, professor of entomology at the Louisiana State University, has informed the writer that he has taken adults during the winter months under logs on batture land of the Mississippi River near Baton Rouge. A few, however, may be found in the field during mild periods of weather throughout the winter. The overwintered adults mate in the spring and the writer has found eggs in the field at Baton Rouge as early as April 13. They have also been taken as late as November 8.

In feeding the adults prefer, as do the nymphs, the growing shoots or developing fruit of their host plants. They are active and capable of strong flight. Morrill (7) has recorded their capture at night and mentions the fact that when an electric light was turned on at night in a room where adults were confined they became restless. This was verified by observations at Baton Rouge.

When handled the adults give off a disagreeable odor. On this account they are sometimes spoken of as "stink-bugs."

COPULATION.

As has been noted by Whitmarsh (13) in the case of *Nezara hilaris*, the male and female of *viridula* usually remain in copulation for a considerable period of time, firmly attached to one another by the tips of their abdomens and with their heads facing in opposite directions. Copulation is also repeated at intervals, as the results of observations on reared individuals given in Table II will show.

OVIPOSITION.

The eggs are placed close together in clusters which, when viewed from above, have much the appearance of pieces of capped honeycomb (fig. 8). Individual eggs are attached to one another, and the cluster to the surface upon which it rests, by an adhesive substance given off by the female at the time of oviposition. In the field the female prefers the underside of a leaf as a location for the egg mass. Egg clusters deposited outside of confinement and examined by the writer have with one exception been made up of from 60 to 116 eggs. A cluster taken on November 3 contained only 36 eggs. Rearing records also indicate that the females sometimes deposit their eggs in smaller clusters, but in such instances this may have been due to their having been disturbed while ovipositing.

RECORDS OF REARED ADULTS IN CONFINEMENT.

Several adults, reared from nymphs, were kept under observation in the insectary until their death, especially with the idea of obtaining data on the period of time elapsing between the time the females emerged from the last nymphal skin and the time of egg laying, the number of eggs laid, copulation, and length of life of males and females. These individuals were confined in jelly glasses containing moist sand, a male and a female being placed in each tumbler. Green tomatoes were used as food and the contents of the tumblers examined daily. Table II includes notes made on some of the pairs.

Several females never laid eggs. One of these issued on July 22 and lived until October 30, part of the time in company with a male. No eggs were found in the ovaries at death. On the other hand, some females that laid eggs had well-formed eggs in the ovaries at death. Seventy-seven eggs were found in the ovaries of the female of Pair L after three clusters, containing 240 eggs in all, had been deposited.

While one female deposited a cluster of eggs 19 days after becoming adult, the average length of this period was nearly four weeks.

TABLE II.—*Length of life, dates of mating and egg laying, and number of eggs deposited by reared adults of Nezara viridula.*[1]

Pair.	Female issued.	Male issued.	Mated.	Male dead.	Female dead.	Eggs deposited.	Number of eggs.	Eggs deposited.	Number of eggs.	Eggs deposited.	Number of eggs.	Total number of eggs deposited.
A	July 13	July 14	July 31; Aug. 12, 15	Aug. 18	Aug. 21	Aug. 12	69	Aug. 20	62			131
B	July 16	July 20	Aug. 10, 11	Aug. 17	Aug. 22	Aug. 8	62	Aug. 14	76			138
C	July 11	July 21	Aug. 6, 9	Aug. 19	Aug. 24	Aug. 20	55					55
D	July 20	July 21	July 31; Aug. 1, 2, 3, 5, 13, 14, 16, 17	Aug. 27	Aug. 26	Aug. 13	52	Aug. 14	9			61
E	July 18	July 19	July 31; Aug. 2, 23, 24	Sept. 11	Sept. 3	Aug. 23	26	Aug. 27	4	Sept. 1	12	42
F	July 28	July 28		Aug. 6	Sept. 17	Aug. 20	59					59
G	Aug. 2	Aug. 2	Aug. 12, 28	Sept. 23	Sept. 1	Aug. 26	10	Aug. 27	65			75
H	July 25	July 25	Aug. 4, 6, 7, 13, 20	Aug. 22	Oct. 1	Aug. 13	70	Aug. 24	35			105
I	Aug. 14	Aug. 14	Sept. 1, 2	Sept. 30	Oct. 13	Sept. 18	78					78
J	Aug. 14	Aug. 14	Aug. 30; Sept. 9, 21, 24, 25	Nov. 2	Nov. 2	Sept. 9	79	Sept. 19	72	Sept. 30	69	220
K	Aug. 14	Aug. 14	Aug. 30; Sept. 6, 10, 18	Nov. 3	Sept. 20	Sept. 6	65	Sept. 10	23	Sept. 18	59	147
L	Aug. 13	Aug. 13	Aug. 27, 28, 30; Sept. 5, 7, 8, 9, 10, 11, 18	Sept. 24	Nov. 18	Sept. 5	87	Sept. 18	83	Oct. 18	70	240

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[1] Temperatures to which individuals were exposed shown in figure 13.

PERIOD OF INCUBATION OF EGGS.

Table III gives data on eggs that were laid by females in the insectary, in which place the eggs were also kept until they hatched. Jars containing the adults and eggs were examined each morning and the date on which eggs were noted is taken to be the date on which they were deposited. In a like manner the date when nymphs were found is taken as the date of hatching.

The eggs composing any one cluster usually hatched at approximately the same time. An exception to this occurred in the case of a cluster of eggs deposited on October 16. Nymphs issued from some of these on October 29, when the thermograph reached a maximum of 87° F. at noon. At 2 p. m.[1] a "norther" caused a sudden drop in temperature, the thermograph registering 34° F. the next morning. No more nymphs were observed to issue on October 30 or 31 when the maximum temperatures were 53° and 63° F., respectively, but on November 1, when the maximum temperature was 70° F., other eggs hatched.

The temperatures to which the different egg clusters were exposed apparently governed to some extent the period of incubation, the period being longer for the lower temperatures.

TABLE III—*Incubation periods of egg clusters of Nezara viridula.*[1]

Deposited.	Hatched.	Days.	Deposited.	Hatched.	Days.	Deposited.	Hatched.	Days.
July 22	July 28	6	Aug. 18	Aug. 23	5	Sept. 4	Sept. 9	5
July 22	July 28	6	Aug. 20	Aug. 26	6	Sept. 5	Sept. 10	5
July 30	Aug. 4	5	Aug. 20	Aug. 26	6	Sept. 6	Sept. 12	6
Aug. 9	Aug. 14	5	Aug. 22	Aug. 28	6	Sept. 6	Sept. 12	6
Aug. 13	Aug. 18	5	Aug. 22	Aug. 28	6	Sept. 6	Sept. 11	5
Aug. 13	Aug. 18	5	Aug. 24	Aug. 30	6	Sept. 18	Sept. 25	7
Aug. 14	Aug. 19	5	Aug. 25	Aug. 31	6	Sept. 27	Oct. 6	9
Aug. 14	Aug. 19	5	Aug. 26	Aug. 31	5	Oct. 16	Oct. 29	13
Aug. 15	Aug. 20	5	Sept. 2	Sept. 7	5	Oct. 18	Nov. 9	22

[1] For temperatures to which eggs were exposed see figure 13.

HABITS OF THE NYMPHS.

The nymph issues from the egg through a circular opening at the top which it makes by removing the cap or lid. The brownish T-shaped egg-burster, by means of which the cap is removed, is usually left in the eggshell when the nymph emerges.

During the first instar the nymphs ordinarily cluster together, often on the eggshells, and apparently do no feeding. After the first molt they begin to search for food and soon become scattered. Subsequent to the first molt, and especially during the later instars, the nymphs are active and when disturbed they often seek protection by moving to places out of the disturber's range of vision. They are found usually upon those portions of the plant on which they prefer to feed—the growing shoots and more especially the developing fruit.

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[1] All references to "clock time" refer to Standard Time.

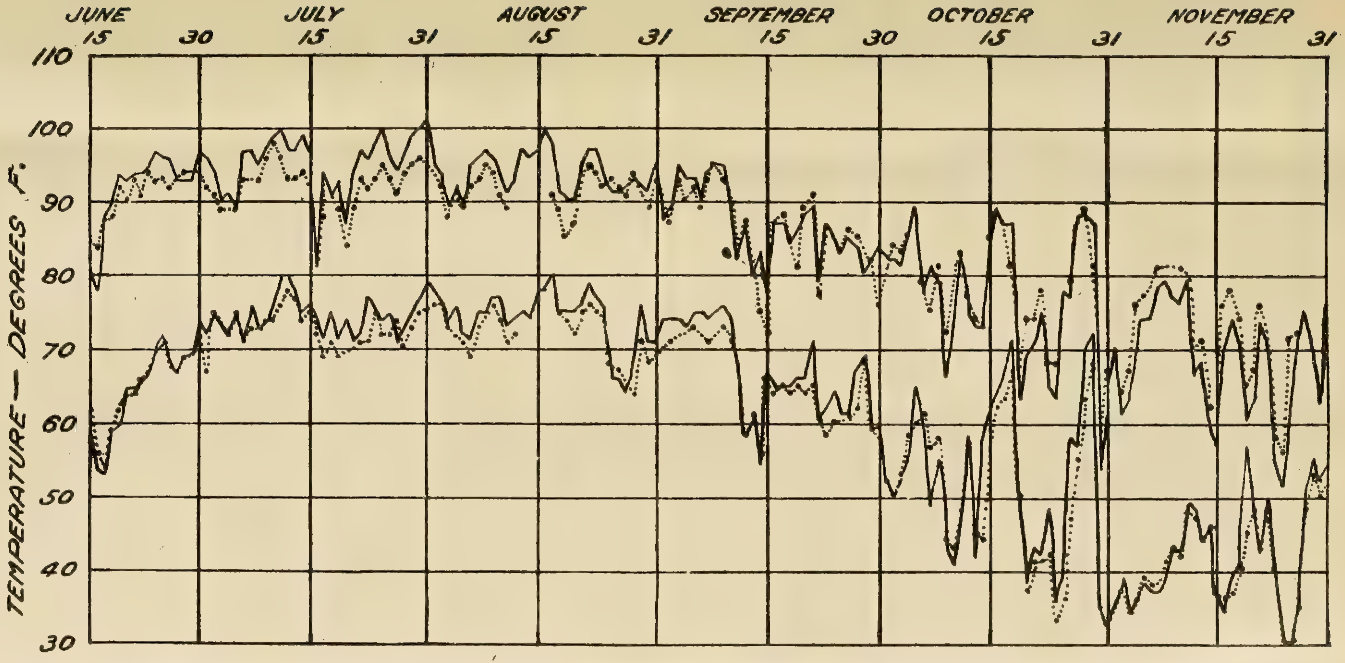

FIG. 13.—Showing temperatures at Baton Rouge, La., during the time when life-history studies of the Southern green plant-bug were conducted. Unbroken line indicates temperature in insectary where studies were conducted. Broken line indicates temperatures for Baton Rouge as given by the United States Weather Bureau.

When handled the nymphs give off a disagreeable odor. This odor is scarcely perceptible in the case of nymphs in the first instar but increases in strength in the succeeding stages.

PERIODS OF NYMPHAL STAGES.

Tables IV and V are introduced to show the minimum number of days spent by nymphs from different egg clusters in the five instars. Table IV refers to nymphs kept in the office and Table V to nymphs kept in the insectary. The nymphs issuing from a single egg cluster were kept together in a cloth-covered jar containing moist sand. Green tomatoes were used as food and proved very satisfactory. Fresh ones were placed in the jars at frequent intervals in order that the food supply might approximate that in the field.

The jars were examined daily, and the dates given for the different lots are those on which the first individual from a certain egg cluster issued from the egg or from a subsequent nymphal instar. It is assumed, therefore, that the first individual to issue from an egg cluster was the first to become adult.

Individuals from any one egg cluster spent about the same amount of time in either of the first two nymphal instars, but during the later instars the periods became less constant. Temperature conditions apparently had an important bearing over this. For instance, during a period of warm weather in the fall a few nymphs in a certain instar would molt; then the temperature would suddenly fall and several days of cool weather follow, no other nymphs molting until this period had elapsed. Periods of several days, therefore, sometimes occurred between the time when the first and last adults appeared. In the fall these periods were sometimes prolonged to 30 days.

The periods spent by the nymphs of different egg clusters in the succeeding instars were apparently influenced by the prevailing temperatures; low temperatures lengthening the periods. This can be seen by comparing the dates given in Table V with the insectary temperatures shown in figure 13.

TABLE IV.—*Minimum length of instars of Nezara viridula based on records of first individuals.*[1]

Lot.	Hatched.	Second instar.	Third instar.	Fourth instar.	Fifth instar.	Adult.
A	July 2	July 5	July 10	July 20	July 26	Aug. 2
B	July 4	July 7	July 13	July 19	July 29	Aug. 8
	Number of days to complete instar.					
A		3	5	10	6	7
B		3	6	6	10	10

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[1] Average of maximum temperatures to which nymphs were exposed, 89° F.; average of minimum temperatures, 80° F.

TABLE V.—*Minimum length of instars of Nezara viridula based on records for first individuals.*[1]

Period spent in first instar.	Days.	Period spent in second instar.	Days.	Period spent in third instar.	Days.	Period spent in fourth instar.	Days.	Period spent in fifth instar.	Days.
June 18–22	4	June 22–26	4	June 26 to July 4.	8	July 4–12	8	July 22–31	9
Aug. 14–17	3	Aug. 22–29	7	July 7–13	6	July 12–22	10	Aug. 3–10	7
Aug. 18–22	4	Aug. 22–26	4	July 7–12	5	July 13–22	9	Aug. 5–12	7
Aug. 19–22	3	Aug. 22–28	6	July 24–30	6	July 26 to Aug. 3.	8	Sept. 7–20	13
Do	3	Aug. 23–29	6	Aug. 26 to Sept. 1.	6	July 30 to Aug. 5.	6	Sept. 11–26	15
Aug. 20–23	3	Aug. 27 to Sept. 2.	6	Aug. 28 to Sept. 4.	7	Sept. 1–7	6	Sept. 23 to Oct. 6.	13
Aug. 23–27	4	Aug. 31 to Sept. 7.	7	Sept. 8–16	8	Sept. 4–11	7	Sept. 24 to Oct. 17.	23
Aug. 28–31	3	Sept. 3–8	5	do	8	Sept. 16–22	6	Sept. 25 to Oct. 18.	23
Do	3	do	5	do	8	Sept. 16–23	7	Oct. 6–29	23
Aug. 30 to Sept 3.	4	Sept. 4–8	4	Sept. 19–27	8	Sept. 16–25	9	Oct. 6–28	22
Aug. 31 to Sept. 3.	3	Sept. 10–19	9	Sept. 20–28	8	Sept. 27 to Oct. 6.	9	Oct. 8–29	21
Aug. 31 to Sept. 4.	4	Sept. 13–20	7	do	8	Sept. 28 to Oct. 8.	10	Oct. 9–28	19
Sept. 7–10	3	Sept. 14–20	6	Sept. 25 to Oct. 5.	10	Sept. 28 to Oct. 9.	11		
Sept. 9–13	4	Sept. 17–25	8			Oct. 5–18	13		
Sept. 10–14	4	Oct. 17–29	12						
Sept. 12–17	5	Oct. 18 to Nov. 10.	23						
Oct. 6–15	9								
Oct. 11–17	6								
Oct. 14–18	4								

[1] For temperatures to which nymphs were exposed see figure 13.

NUMBER OF GENERATIONS ANNUALLY.

As has been stated, eggs have been taken in the field at Baton Rouge as early as April 13, and as late as November 8, while nymphs in the fifth instar were observed December 23. Life-history studies were conducted in an insectary where both the maximum and minimum temperatures are slightly higher than those given by the Weather Bureau of the United States Department of Agriculture for Baton Rouge (fig. 13). Under these conditions it would appear that, while the egg and nymphal stages may be passed in about a month, during the summer months, adults usually do not begin egg-laying until nearly four weeks after molting the last nymphal skin. Field and insectary observations indicate that four generations develop annually in the field at Baton Rouge.

NATURAL ENEMIES.

In spite of the disagreeable odor of the species of the genus, the Bureau of Biological Survey has recorded finding specimens of Nezara in the stomachs of certain birds, but it appears to have been always *hilaris* that was found. *N. viridula* is probably also eaten.

Morrill (7) and Whitmarsh (13) mention the fact that the eggs of *hilaris* are parasitized by a species of Trissolcus, and it would thus appear that the eggs of *viridula* would also be attacked by this parasite, although many egg clusters of *viridula* collected in the field failed to show any evidence of parasitism.

A PARASITE.

Trichopoda pennipes Fab.—Morrill (7) mentions the presence of the egg of a tachinid fly on a nymph in the fifth instar collected at Quincy, Fla., among a lot of 39 specimens in stages susceptible to parasitism by tachinids. The writer has found tachinid eggs common on adults taken at Baton Rouge, and in all cases where the flies have been reared they have proved to be adults of *Trichopoda pennipes* (fig. 14), which is known to attack a number of the larger Hemiptera. Upon completing their growth the larvæ left the bodies of their hosts and transformed to puparia in the soil. The puparium is cylindrical in shape with rounded ends. It measures about 7 mm. in length and 3.5 mm. in width and when fully colored is dull reddish black.

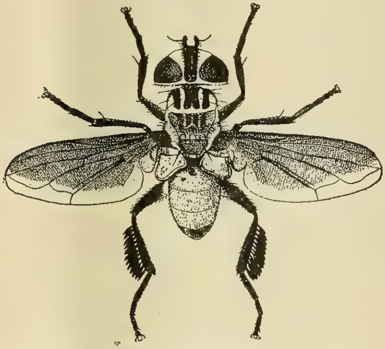

FIG. 14.—*Trichopoda pennipes*, a tachnid fly parasitic on the Southern green plant-bug: Adult. Enlarged about 3 diameters. (Chittenden.)

Of 73 adults collected on mustard December 6, 1915, 13 males and 5 females, or nearly 25 per cent, bore tachinid eggs. Most of the adults had only one egg upon them, but one had two, two three, and one four. Of the 26 eggs on all adults, 4 were on the dorsal surface and 20 on the ventral surface, while 2 were on the eyes. Four eggs were found on the head, 10 on the prothorax, 3 on the mesothorax, 2 on the metathorax, 5 on the abdomen, and 2 on the wing covers. An egg has also been observed on the femora of one of the fore legs.

The surface of the egg that is quite firmly attached to the host is usually flat. The opposite surface is strongly convex and is ellipsoidal in outline. The entire surface of the egg is glistening and is marked by minute hexagonal reticulations. The egg measures about 0.54 mm. in length and 0.35 mm. in width. Its color varies from white to gray, apparently being white when first deposited.

PREDACIOUS ENEMIES.

Podisus maculiventris Say.—A single instance of this common pentatomid bug preying upon *Nezara viridula* was noted in the field at Baton Rouge during December, 1914. This individual had a nymph in the fifth instar impaled on its beak.

Euthyrhynchus floridanus L.—Among the notes in the Bureau of Entomology files made by the late H. M. Russell, mention is made of two predacious enemies observed by him in Florida during 1907.

Specimens of *Nezara viridula* accompanied the notes. At Dade City, on November 11, an adult of the pentatomid bug *Euthyrhynchus floridanus* was found with its rostrum thrust into a mature individual.

Bicytes quadrifasciata Say.—Mr. S. A. Rohwer of the Bureau of Entomology states that a bembecid wasp which Mr. Russell collected at St. Leo, Fla., October 22, 1907, belongs to this species. The specimen was taken while in flight with an adult of *Nezara viridula* grasped in its mandibles.

CLIMATE AS A CONTROL FACTOR.

Whitmarsh (13) considers climate an important factor in the natural control of the related *Nezara hilaris* in Ohio. Cold winters, or periods of cold weather following unusually warm weather during the winter months, killed many individuals of that insect. Observations made in connection with *Nezara viridula* in the Gulf States indicate that sudden drops in temperature during the winter months kill many individuals in the field. In Florida Mr. H. M. Russell found, on December 5, 1907, "a few dead adults after the freeze" of the preceding night. Writing from Brownsville, Tex., on May 25, 1909, Messrs. D. K. McMillan and H. O. Marsh stated that the "species has been conspicuously absent for several months, though very abundant during the fall and early winter * * *" and added "It may be that the two freezes of January 15 and early February may have had some influence."

The writer has found that in the insectary at Baton Rouge individuals, especially in the nymphal stages, are sometimes killed by low temperatures during the winter months.

METHODS OF ARTIFICIAL CONTROL.

It is well known that the pentatomid bugs and other large plant-bugs are quite resistant to contact insecticides, and the experiments indicate that it is difficult to control the southern green plant-bug by using insecticides of this type.

SPRAYING WITH NICOTINE SULPHATE.

Individuals in various nymphal instars, as well as adults, have been drenched with dilutions of nicotine sulphate which contained 40 per cent of nicotine by weight in combination with yellow laundry soap at the rate of 2 pounds to 50 gallons of water. These individuals were then kept under observation in the insectary and the effects of the different mixtures upon them noted. A dilution of 1 part nicotine sulphate to 300 parts of water killed all nymphs, but even in the proportion of 1 to 100 the nicotine had little effect on the adults. A dilution of 1 to 600 was not effective against nymphs in the third, fourth, and fifth instars. On the day following the treatment over 50 per cent were active, and even in the case of nymphs in the third instar at least 50 per cent survived.

SPRAYING WITH KEROSENE EMULSION.

Experiments with strong mixtures of kerosene-soap emulsion also gave unsatisfactory results. One part of stock solution, made up of kerosene and yellow laundry soap, to two parts of water did not kill all nymphs that were drenched with it. Undiluted kerosene, as would be expected, quickly killed individuals in both the nymphal and adult stages.

In the experiments it was noted that nymphs which, immediately after being drenched with a contact insecticide, apparently showed signs of approaching death, recovered later.

HAND PICKING.

Hand picking can be done profitably where valuable vegetable crops are being attacked. The bugs may be collected in a receptacle containing a little water coated with a film of kerosene, or some other collecting device may be used. Where the bugs occur on other than low-growing plants the receptacle may be a pan or wide-mouthed dish and the bugs may be brushed or knocked from the plants into it. Collecting can be done best in the early morning, or during cool weather, when the bugs are sluggish. In addition to collecting and destroying the adults and nymphs, the destruction of egg clusters is recommended.

In order to secure a maximum reduction in the amount of damage done to the plants, hand picking not only should be carefully done, but should be put into practice when the attack begins.

USE OF TRAP CROPS.

The adults are attracted to mustard and turnips during the fall, as indicated by the collections referred to below. These were made from a few plants in a garden at Baton Rouge where serious injury by the species is seldom noted. About 15 minutes a day were spent in the work, all collections being made from the same plants. It would appear that after the first collection the succeeding adults were individuals that came to the plants from the time of one collection to the next, it being unlikely that many adults escaped at the time each collection was made.

On October 24, 47 adults were collected; on October 25, 81; on October 28, 79; and on October 31, 42. In addition to the foregoing 249 adults, 148 nymphs were collected.

The fact that nymphs and adults are often very abundant in the late fall on turnip and mustard suggests that a few of these plants, or others on which the southern green plant-bug is found to congregate, might be grown as trap crops in sections where serious injury occurs. The bugs might be hand picked or killed by spraying with a strong contact insectide or by using a gasoline torch. Even if it were found necessary, in order to kill the nymphs and adults economically, to use measures that would injure the plants, the operation might prove profitable in areas where serious damage occurs. Where the plants have not been grown especially as trap crops the destruction of the nymphs and adults when they congregate in large numbers would assist materially in reducing their destructiveness.

SUMMARY OF CONTROL MEASURES.

It would seem that spraying with a contact insecticide is not practical, unless employed in connection with trap crops where injury to the plants by the insecticide is not of importance. While it is possible to use mixtures strong enough to kill even the adults, the injurious effects of the insecticide upon the plants, as well as their present cost, would have to be considered.

The writer is inclined to agree with Watson (14) that hand picking is the most satisfactory control measure where valuable vegetable crops are seriously attacked, but for less valuable crops it is questionable whether this could be profitably done.

The fact that the adults congregate on turnip and mustard late in the fall in Louisiana suggests that a few of these, or other plants upon which they congregate, might be grown to serve as a trap crop.

GENERAL SUMMARY.

A pentatomid bug, *Nezara viridula* L., here given the common name of the southern green plant-bug, causes severe injury to cultivated crops in the southern portion of the Cotton Belt of the United States. Among the vegetable and truck crops injured are tomato, beans, Irish potato, sweet potato, okra, mustard, and turnip.

The species is widely distributed over the world and attacks a great variety of plants.

The adults and nymphs cause injury by inserting their beaks into the plant tissue and extracting the juices. Young growing shoots and developing fruit are most seriously injured.

Life-history studies have been carried on at Baton Rouge, La., in an insectary where the average maximum and minimum temperatures are slightly higher than those given by the United States Weather Bureau for the same locality. One female began egg-laying 19 days after becoming adult, although the average length of this period for the several females under observation was about four weeks. The number of eggs deposited by different females varied greatly. Some laid no eggs, while one deposited 240 and had 77 well-developed eggs in the ovaries at death. The eggs are placed in clusters, and in the field they have been found always on the underside of leaves. These clusters were made up of from 36 to 116 eggs.

In the insectary the minimum period necessary for the incubation of the eggs was 5 days. For the five nymphal stages the minimum periods were 3, 4, 5, 6, and 7 days, respectively, a total of 30 days for the egg and nymphal stages. The temperatures to which the eggs and nymphs were exposed apparently had a bearing on the length of the period of any stage. Development was more rapid during the summer than during the fall.

Eggs have been found in the field at Baton Rouge as early as April 13 and as late as November 8. It is probable that in this latitude four generations may develop in a year. Adults are found hibernating during the winter months, but they also occur on plants in the field during mild periods of weather during this season.

Four enemies have been observed, the tachinid fly *Trichopoda pennipes* Fab. apparently being the most important.

As a method of control the collection and destruction of eggs, nymphs, and adults is recommended where valuable vegetable crops are attacked. Adults congregate on turnip and mustard during the fall and a few of these plants, or others on which they congregate, might be grown as trap crops in sections where serious injury by the species occurs. The adults may be collected from these plants and destroyed.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 690

Contribution from the Bureau of Markets,
CHARLES J. BRAND, Chief.

Washington, D. C. ▼ July 23, 1918

MARKETING PRACTICES OF WISCONSIN AND MINNESOTA CREAMERIES.

By Roy C. Potts, *Specialists in Marketing Dairy Products.*

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INTRODUCTION.

As information regarding the methods of marketing employed by the creameries in the two largest butter-producing States, Wisconsin and Minnesota, might be of interest to dairy farmers and of value to creamerymen, the marketing practices of these creameries were studied by the United States Department of Agriculture in cooperation with the University of Wisconsin, the University of Minnesota, and the Dairy and Food Department of the latter State.[1] In this bulletin the more important business phases of the marketing practices of these creameries and the market distribution of creamery butter are presented.

FACTORS WHICH INFLUENCE THE MARKETING PRACTICES OF CREAMERIES.

The business operations of a creamery may be classified as those which are primarily (1) manufacturing practices, (2) business practices, and (3) marketing practices. The manufacturing practices include primarily the technical and scientific methods of converting the raw material purchased into various manufactured products. The business practices relate particularly to the administrative organization, including the accounting methods for keeping records of the finances, the products handled, supplies purchased and used, and the investments in the business. The marketing practices are concerned chiefly with the buying of the raw material from producers and the marketing of the products produced. In a general way the buying and selling policies or practices are usually closely related to the business organization and management.

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[1] Those participating directly in the investigation were Prof. B. H. Hibbard, Asher Hobson, and Paul Gillen, of the University of Wisconsin, Dr. L. D. H. Weld and O. B. Jesness, of the University of Minnesota, and Chris Johnsen of the Minnesota Dairy and Food Department.

NOTE.—This bulletin should be of interest to creamery men and dairy farmers in the United States.

For purposes of comparison from the standpoint of business organization in its relation to the marketing practices, creameries may be divided into two classes; (1) cooperative; and (2) proprietary and noncooperative stock company corporations. As a rule, cooperative creameries, except when a form of patronage dividend is employed, do not buy the milk or cream from the farmer. At most of the cooperative creameries of Minnesota, and at many in Wisconsin, the raw material is received and churned into butter and after the butter is marketed, the cost of manufacturing, plus a small amount for a sinking fund, is deducted from the net return from the sale of the butter and the balance is prorated among the patrons in accordance with the amount of butter fat each has delivered. The stock dividends are usually limited to 6 per cent, and under the cooperative law of Wisconsin enacted in 1911 the nonstockholder is allowed one-half of the trade dividend paid to the stockholder.

Proprietary and stock company creameries usually purchase the butter fat from the farmers at a price based upon the quotations of a recognized wholesale butter market. Some operate on a basis which is practically cooperative by returning to the farmer the average price received for the butter, less a fixed charge for manufacturing, which varies from 2 to 4 cents per pound. Another basis which is used to some extent is that of allowing the creamery the "overrun"[1] as compensation for the cost of manufacturing.

In creameries owned by an individual the marketing policies and practices are determined by the proprietor, while in cooperative and stock company creameries the board of directors usually selects a business manager or delegates the duties of business manager to one of the officers, or to the butter maker. In order to maintain the operating expenses at as low a figure as possible, most cooperative cerameries have generally limited the duties of the business manager of the creamery to a minimum and, therefore, those practices have been employed which require the least expenditure of time and expense. After the butter maker has been employed for the year and the time and method of payment to the patrons has been decided, the detailed business features have consisted primarily of the keeping of a record of the amount of cream delivered by each patron, the delivery to the transportation agency of the butter produced, and the consignment or shipment of it to market. The problem of transportation and market distribution for the most part have been taken care of by the transportation agencies and wholesale distributors in the market.

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[1] The "overrun" is the difference between the amount of butter fat paid for and butter produced.

BUYING POLICIES AND METHODS OF CREAMERIES.

The methods employed in marketing milk and cream to creameries have undergone marked changes in recent years. Prior to the general use of cream separators on farms, the local creamery prevailed, and practically every creamery obtained its supply of raw material from farms in the vicinity of the creamery or skimming stations which were reached by wagon routes. Reports obtained in 1915 from 900 creameries in Wisconsin and Minnesota showed that only 27 received whole milk exclusively, 243 received both milk and cream, and 630 received separated cream only.

Usually local cooperative creameries required the farmer either to pay the costs of country collecting or to deliver the milk or cream to the creamery in person or as might be arranged. Reports from 127 creameries in Wisconsin showed that 71 creameries included the cost of collecting in the operating expenses while 54 charged the cost of collecting to the patron and 2 employed a combination of these two methods. The cost of collecting varied from 0.5 to 4.6 cents per pound butter fat, with an average cost of approximately 1.7 cents. The patrons of many local creameries in Minnesota organized "rings" of two or more farmers, in which each took his turn in hauling his own and the cream of the others. This method of hauling gave each member the full benefit of a delivered price. At about 20 per cent of the creameries, all or a part of the cream was gathered by routes, the average length of which was about 23 miles. At eight creameries which gathered their cream mostly by routes the average cost of collecting 952,449 pounds of butter fat by routes was 2.7 cents per pound.

At some creameries it was a common practice for the patrons to deliver their cream every two or three days, although some delivered only once a week. Those creameries which required daily deliveries in summer, often permitted delivery every other day in winter, and when three deliveries a week in summer were required, two were permitted in winter. Many creameries required the cream to be delivered in the morning, while others accepted it at any time during the day.

In the transportation of cream by railroad to 40 centralizing creameries, the average cost was reported to be 1.63 cents per pound of butter fat. This, however, did not include the country collecting or delivery cost incurred by the farmer in the delivery of his cream to the receiving or shipping station.

BUYING OF CREAM BY GRADE.

The infrequency of delivery of cream to creameries and other factors have resulted in the marketing of considerable cream of inferior quality. A number of creameries, recognizing the relation of poor cream to poor butter, which on the market sells at lower price (see fig. 1), have sought to encourage more frequent deliveries by establishing grades for cream and by paying different prices for the various grades. About 15 per cent of the creameries in Minnesota from which information regarding cream grading was obtained had employed a grading system. Usually two grades were employed and a premium of 2 or 3 cents per pound of butter fat was paid for the better grades of cream. Many creameries reported that they were in favor of grading and intended to adopt such a system.

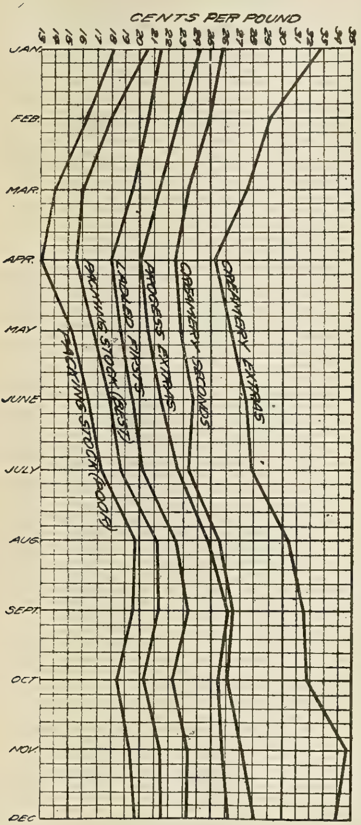

FIG. 1.—Average monthly quotations on the New York market for various classes and grades of butter for the year 1914.

The general opinion of those creameries which had graded their cream was that the quality of the cream received had been greatly improved. Those which had noted the effect of cream grading on the price received for their butter stated that an increase had been obtained. Eight creameries which churned the first and second grade cream separately showed an average increase in price of 3.6 cents per pound for the butter churned from the first grade cream. At some creameries, the patrons who supplied second-grade cream objected to the grading system and in some cases a few patrons had been lost.

BASIS OF PRICE PAID FOR CREAM.

The usual practice of the cooperative creameries of Wisconsin and Minnesota was to prorate the net receipts among the patrons according to the amount of butter fat each had furnished. Those creameries in Minnesota which did not operate on the cooperative basis, usually based their buying price of butter fat on the New York butter quotation for "extras." Creameries in Wisconsin used either the Elgin or Chicago quotation, and frequently paid premiums above the quotations when the Elgin quotation was used.

The centralizing creameries in these States gave consideration to the price paid by local creameries, also the market quotations at New York, Chicago, Elgin, and Boston. When country cream receiving stations were operated by centralizing creameries, the price paid to the patrons for butter fat was sometimes as much as 4 cents below New York "extras." Direct cream shippers received approximately the market quotation for "extras."

FREQUENCY OF PAYMENT TO PATRONS.

About 80 per cent of the cooperative creameries of Minnesota paid their patrons once a month and 15 per cent paid twice a month. The frequency of payment varied with the others. The system of paying the patrons monthly may be accounted for by the usual method of prorating the monthly net receipts according to the amount of butter fat each patron had delivered. The noncooperative creameries in Minnesota were about equally divided on the methods of paying once a month, twice a month, and at time of delivery. Of 250 creameries in Wisconsin, 48 per cent paid monthly, 39 per cent semimonthly, and the rest either daily, semiweekly, or weekly. Nearly all centralizing creameries paid for each shipment of cream as it was received.

MARKETING OF CREAMERY BY-PRODUCTS.

Skim milk and buttermilk are natural by-products of creameries. It was found that usually the skim milk was returned to those patrons who delivered whole milk, at the rate of 80 per cent of the amount of whole milk delivered.

Frequently the buttermilk at country creameries was contracted to a regular buyer or to patrons at 10 cents per can, or at 1 to 1½ cents per gallon. Creameries located in large cities often sold buttermilk to hotel and other city trade at 2 to 10 cents per gallon.

Ice cream, while not ordinarily considered as a creamery by-product, was manufactured as a creamery "side line" in about 20 per cent of the creameries in Wisconsin, and 2.1 per cent of those in Minnesota, by the converting of a part of the milk and cream supply into this product. Some creameries made only a few gallons per day, while others engaged in ice-cream production more extensively. In most instances it was sold to local trade in the city in which the creamery was located. The annual receipts from the sale of ice cream at the creameries varied from less than $1,000 to over $35,000.

TRANSPORTATION OF CREAMERY BUTTER TO MARKET.

The shipment of butter to market was usually made by refrigerator freight. The schedules in most instances provided for weekly or semiweekly shipments. The butter produced after the shipping day, was usually held in storage at the creamery. The facilities for storage at most creameries consisted of insulated storage rooms which were kept cold either by the use of ice or mechanical refrigeration. About 92 per cent of the creameries used ice, as it was considered cheaper.

In furnishing refrigerator service to local creameries, the railroad company either set out an iced refrigerator car on the sidetrack at the creamery's shipping station or carried a refrigerator car in a local way freight, which made it necessary for the creamery to deliver its butter to the depot where it was ready when the refrigerator car arrived. The consolidation of less-than-carload shipments into full carloads was effected at division points, where a number of cars were assembled on parallel tracks or along a platform, and the butter destined to different markets was transferred into separate cars. (See fig. 2.) The butter which had arrived over the different divisions was thus loaded so that each shipment could be forwarded by through fast freight to its final destination.

The transportation charges and routing of shipments varied somewhat in different sections. Northern Minnesota butter in less-than-carload lots, routed rail-lake-and-rail via Duluth to Buffalo and points beyond, took a combination of rates on Duluth and Buffalo. The tariffs of the lake carriers required a minimum of 15,000 pounds of "dairy products," i. e., butter, eggs, and dressed poultry, in straight or mixed lots from one shipper for one destination and delivery. For the purpose of economizing in freight charges the Minnesota shippers employed an agent at Duluth who effected consolidation of the shipments at that point.

The all-rail shipments moved through Chicago, while many from Minnesota moved through St. Paul. The less-than-carload shipments took the second-class rate to Chicago, while the carload shipments took the third-class rate, with a minimum weight of 20,000 pounds. Usually the less-than-carload shipments were consolidated by the railroads at St. Paul, Chicago, and other points in order to make full cars for separate destination, which resulted in quicker time in transit to the final destination. The through rate to eastern points was a combination rate on St. Paul or Chicago. The second-class rate applied to that portion of the routing east of St. Paul or Chicago, and was the same for carload and less-than-carload shipments, so that the through carload rate was very little lower than the through less-than-carload rate.

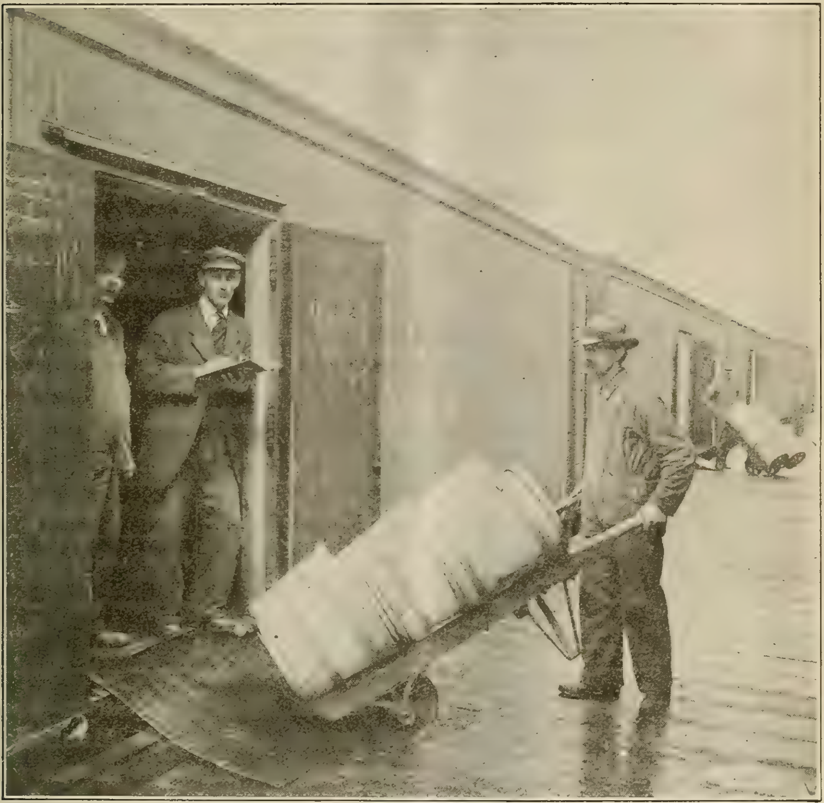

FIG. 2.—Consolidating less-than-carload shipments destined to the same market into one car.

SHRINKAGE OF BUTTER FROM CREAMERY TO MARKET.

Shrinkage is usually considered as the difference between the weight of butter at the creamery and at the market. Since only tub butter is sold on the weight-at-market basis, the investigations were confined to this style of package. Prior to the date on which the net weight amendment to the Federal food and drug act became effective many creameries did not weigh their butter carefully before shipping. This amendment requires that the net weight of each package be marked upon it. If the weight is overmarked the creamery becomes liable to prosecution, and if undermarked the creamery may be paid for less than the actual net weight of the butter if the receiver or buyer accepts the weights marked on the packages by the creamery. In the investigation, comparisons of creameries' weights and receivers' weights were made of 1,044 tubs, consisting of 55 shipments of Minnesota butter, forwarded to 32 firms on seven different markets. The net weight at the market was 605.5 pounds less than the weight at the creamery, or an average of 0.58 pounds less per tub than the creameries' weights.

Considerable variation in shrinkage was observed in the various shipments. One shipment showed an average loss of 2.3 pounds per tub, while another apparently gained 1.37 pounds per tub. These wide variations may have been due to errors in weighing at the creamery and the methods of weighing employed by the receivers of butter in the market. In some markets fractional pounds were not considered by the receivers and only a portion of the tubs were stripped to get the average tare which was used in estimating the net weights for the entire lot.

In a more detailed investigation, including both Wisconsin and Minnesota butter, where weighings were made to one-fourth pounds by representatives of the department, both at the creamery and in the market, the following results were obtained:

State.	Chicago shipments.		New York shipments.	
	Number of tubs.	Average shrinkage.	Number of tubs.	Average shrinkage.
Wisconsin	160	0.399	46	0.418
Minnesota	149	.210	345	.217

The actual average net shrinkage on the Wisconsin butter was approximately four-tenths of a pound per tub, and on the Minnesota butter only two-tenths of a pound. The difference in the shrinkage of the butter per tub when the weighings were made in the market by the receivers, and when made by representatives of the department, may be explained by the differences in the methods of weighing.

The representatives of the department, both at the creamery and in the market, obtained the gross weight of the tub when filled and when empty (not including the tub cover) to the nearest quarter pound. The difference between these weights was taken as the net weight of butter.

MARKET METHODS OF WEIGHING.

The receivers on the market usually weigh each tub in the shipment separately to obtain its gross weight. In obtaining the gross weight, fractions of pounds usually were disregarded; in fact, most receivers require that the beam of the scale touch the upper rest. If it merely plays lightly on or above the center, practically a whole pound is lost to the creamery, as the next lower pound is taken as the weight. After each tub has been weighed (gross), a few are stripped—that is, the butter is removed and weighed. (See fig. 3.) In this weighing all fractions are again disregarded and up-weights usually are required. By this practice it is possible for a creamery to lose practically a pound on certain tubs, and occasionally it may lose even 2 pounds through a slight error in both the gross and net weights. This, however, is not frequent, for the results obtained showed that ordinarily the difference between the weights made at the creamery and the weights obtained at the market under the prevailing market practice of approximating the net weights was from one-half to three-fourths of a pound per tub. A portion of this difference is shown by the weighings made by the department's representatives to be due to an actual shrinkage or loss in the net weight of the butter while in transit to market. With the increase in the market value of butter during recent years, the financial loss to the creamery caused by the present method of approximating the net weight is much larger than it was formerly when the present market method of weighing was established.

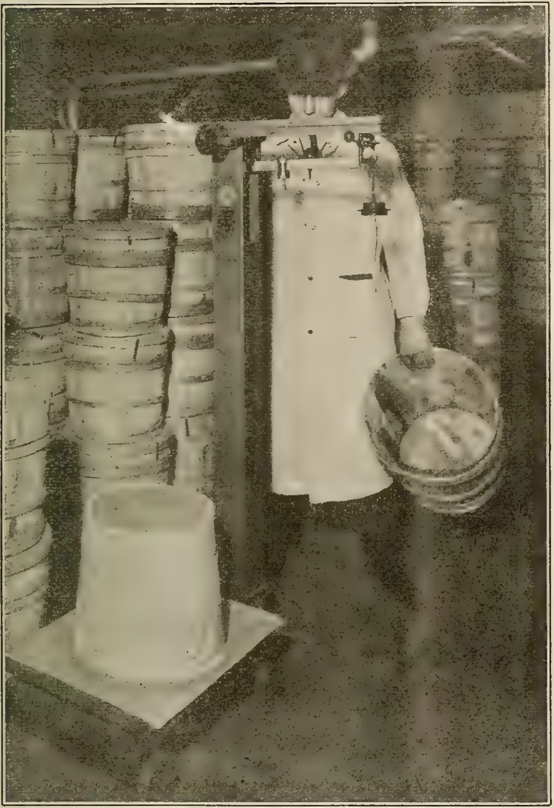

FIG. 3.—In making "test-weights" to determine the tare weight of the tub, strong up-weights are usually required.

Occasionally a weigher will "give and take"; that is, recognize a full pound even if the beam of the scales balances merely on the center. In other words, "snug up-weights" are not required when the stripped tub of butter is weighed. By recognizing half pounds the weights obtained would approximate closely the actual net weight and eliminate a large part of the difference between the weights at the creamery and the market.

MARKETING OF BUTTER BY CREAMERIES.

The various buyers of creamery butter may be classified as consumers, retailers, jobbers, and wholesalers. The patrons comprise the principal outlet for the sale of butter direct from creameries to consumers. Approximately 4 per cent of the butter produced by Wisconsin creameries, and 6 per cent of that produced in Minnesota was sold to the creamery patrons. At some creameries nearly all the patrons obtained their butter from the creamery while at others the sales to patrons were limited.

Creameries located in large cities sold a large part of their butter at some seasons to retailers, while some of the country creameries sold practically none to this class of tarde. Of the total amount of creamery butter produced in Minnesota, less than 7 per cent was sold to retailers, while in Wisconsin approximately 15 per cent was marketed in that way.

Many jobbers who function as wholesale distributors in supplying retail trade bought a large portion of their supply in print packages from creameries. Centralizing creameries located in large cities sold local grocers large quantities of butter in prints. That which was not sold locally was usually marketed through their own sales organization or distributed in prints or tubs through jobbing agents. The principal cities to which butter was shipped to wholesale butter distributors were Chicago, New York, Boston, and Philadelphia. These four markets received about two-thirds of the butter produced in these two States. Chicago received approximately one-half of Wisconsin's butter and less than 15 per cent of Minnesota's, while over one-half of Minnesota's was marketed in New York City, and less than 10 per cent of Wisconsin's.

CREAMERY METHODS OF MARKETING.

The general practice of Wisconsin and Minnesota creameries in marketing tub butter was to ship it to wholesale receivers upon an informal agreement between the creamery and the receiver under which the price to be received usually was based upon a designated market quotation for "extras." About 80 per cent of the Wisconsin creameries based their agreements on the Elgin quotation; 16 per cent on Chicago; and 4 per cent on the New York quotation. Minnesota creameries which shipped to New York generally used the New York quotation as the basis of their price agreement. The agreements frequently varied, including market quotation net f. o. b. shipping station; market quotation net f. o. b. receiver's station;

market quotation plus a premium less freight; market quotation plus a premium less freight and cartage; or market quotation plus a premium less freight, cartage, and commission.

Of those Wisconsin creameries which sold on the basis of the Elgin quotation, approximately 70 per cent received the flat Elgin quotation and the others a premium of from 1 to 4 cents above. When the Chicago quotation was used, the flat quotation generally prevailed although the net price received varied from ½ cent below to 1½ cents above. It is estimated that approximately 15 per cent of the creameries of Minnesota sold their butter f. o. b. the shipping station; 85 per cent had freight charges deducted, and 37 per cent were charged a commission. The chief reason for deducting a commission was that many of the creameries were accustomed to it and by allowing a commission to be deducted the gross price obtained could be expressed in the form of a premium above the quotation. By allowing a commission of ½ cent and a freight charge of approximately 1½ cents to be deducted, a creamery would receive a gross price of 2 cents above market quotation, which actually was equal to the quotation net at the shipping station.

A common custom of the creameries was to forward their shipments on order bills of lading and to draw a draft against the consignee which was passed to their local bank for collection or credit. When a sight or demand draft is used it is attached to the original copy of the "order" bill of lading. The draft usually is drawn to cover from 60 to 75 per cent of the value of the shipment. One advantage of the order bill of lading is that the consignor has control of the shipment until the draft is paid, and the creamery's risk of collection for the goods is reduced by that amount. The use of this form of a bill of lading is desirable when demand or sight drafts are used and shipments are made to firms whose financial standing has not been ascertained.

MARKET DISTRIBUTION OF CREAMERY BUTTER.

The following method of wholesale market distribution of creamery butter was found to be prevalent:

Upon the arrival of a freight shipment of butter at a terminal market, a notice was sent by the railroad to the consignee. The butter was trucked to the receiver's salesroom, where it was weighed, inspected, and held for sale or disposal.

As a means of identifying the shipments from each consignor, the receiver usually furnished the creamery with a rubber stamp or stencil which was used on the top of each tub. This stamp gave the name and address of the consignee, and the serial number of the creamery. These stencil numbers were frequently removed by the receiver before the butter was sold.

During the season of surplus production, beginning about April 1 and ending September 1, that portion of the market receipts which did not pass into immediate consumption was usually put into public cold storage either by the receiver or by other buyers of butter for storage purposes. The rates for storage varied according to the length of time that the butter was held. Ordinarily, storage rates were figured at three-fourths of a cent per pound for a storage period of six months. As a temperature of zero degrees F. or below was maintained in the storage rooms, the butter usually deteriorated but little in quality. Butter stored in warehouses was usually insured for approximately 80 per cent of its value at a charge of from 60 cents to $1.50 per $100, depending upon the character of construction of the storage. The warehouse receipt and the insurance certificates were used as collateral in obtaining loans on butter in storage. The usual rate of interest on these loans was 6 per cent. The largest quantities were placed in storage during May, June, and July, and the withdrawal from storage was heaviest from September 1 to April 1. Approximately 70 per cent of all butter stored was received into storage during the months of May, June, and July. Approximately 74 per cent was taken from storage from September 1 to April 1.

The business of the wholesale receiver is, in general, organized about as follows: A general manager supervises the entire business and gives particular attention to securing the supplies of butter, often personally supervising the soliciting of shipments from creameries. The cashier has general supervision of the clerical force and bookkeepers. The "floor man" in the receiving room is an expert judge of butter quality and oversees the grading and taking out of the orders. The sales force keeps in close touch with the general manager, floor man, and the credit department. The credit department usually consists of a credit clerk who is responsible to the cashier and the general manager.

Many wholesale receivers function also as jobbers. Jobbers may operate as wholesale receivers or they may obtain their supply of butter from wholesalers. The retail stores are supplied by jobbers who take orders and deliver the quantity and quality of butter in such size and style of packages as the retailers' trade requires. In addition, the jobbers also supply such trade as restaurants and hotels, dining cars and boat service, and out-of-town retailers and jobbers.

The marketing of creamery butter from producer to consumer is not dependent upon any one system of wholesale or retail distribution. (See fig. 4.) Local creameries, cream stations, and centralizing creameries may act as agents of the producer or they may be cash buyers of his milk and cream. The exclusive distributing agent of a centralizing creamery may receive a salary, a salary and commission on sales, or a commission alone. Not infrequently the butter is purchased on a regular contract basis. Thus the ownership of the goods passes, while in the former instances it remains with the creamery. The cooperative marketing associations may be selling agents of local creameries. A brokerage agent usually represent a jobber or wholesaler in buying butter from a centralizing creamery or wholesale dealer. Cold-storage firms do not usually buy or sell butter, although they frequently make loans on goods put in their storages.

COST OF MARKET DISTRIBUTION OF CREAMERY BUTTER.

As creamery butter in passing from producer to consumer may be handled through different channels of trade, the average margin or approximate cost in one channel may not represent the cost in any other.

The following in general was found to be approximately the usual margin on tub butter when it passed direct from wholesale receiver to jobber, from jobber to retailer, and then from retailer to consumer.

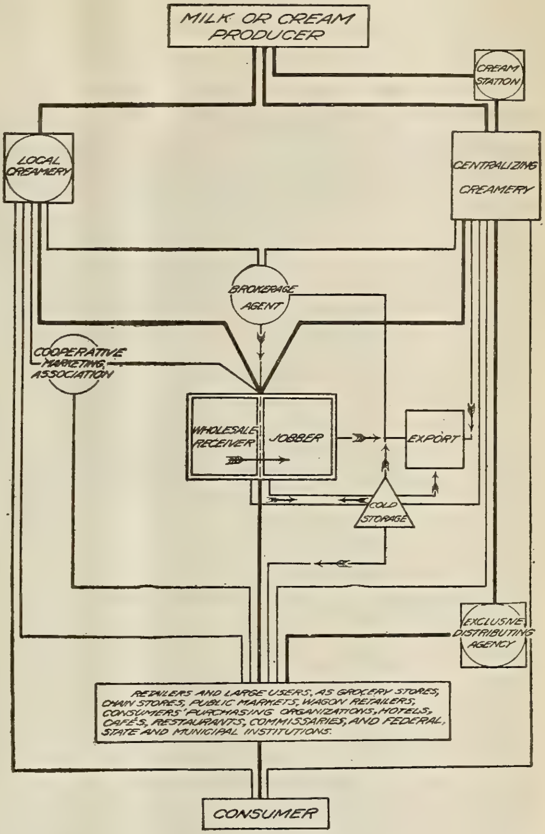
MILK OR CREAM PRODUCER
CREAM STATION
LOCAL CREAMERY
CENTRALIZING CREAMERY
BROKERAGE AGENT
COOPERATIVE MARKETING ASSOCIATION
WHOLESALE RECEIVER
JOBBER
EXPORT
COLD STORAGE
EXCLUSIVE DISTRIBUTING AGENCY
RETAILERS AND LARGE USERS, AS GROCERY STORES, CHAIN STORES, PUBLIC MARKETS, WAGON RETAILERS, CONSUMERS' PURCHASING ORGANIZATIONS, HOTELS, CAFÉS, RESTAURANTS, COMMISSARIES, AND FEDERAL, STATE AND MUNICIPAL INSTITUTIONS.
CONSUMER

FIG. 4.—Channels of distribution of creamery butter from producer to consumer. The most usual channels are indicated by the heavy lines. The rectangles denote a change of ownership of goods and the circles an intervening agency between seller and buyer—usually a cooperative organization representing the seller.

	Cents.
Wholesaler's gross margin	$\frac{1}{2}$
Jobber's gross margin	$1\frac{1}{2}$
Retailer's gross margin	4
Total	6

These margins do not always prevail, for a wholesale receiver may handle a carload of butter for a quarter of a cent per pound and a chain store[1] may retail to consumers on a gross margin of 3 cents per pound.

Butter which has been carried for several months in cold storage and has incurred charges such as interest on loans, storage, insurance, and drayage and which has risked deterioration, may be sold at a net loss or a net profit of several cents, depending upon the quality of the butter and its market value when taken from storage. The margin on butter purchased by a retailer direct from a creamery may vary from 2 cents to 10 cents per pound. Some retailers follow closely the wholesale market quotations and base both their buying and selling prices on it. The margins on butter depend to a considerable extent upon market conditions, trade requirements, and the service given.

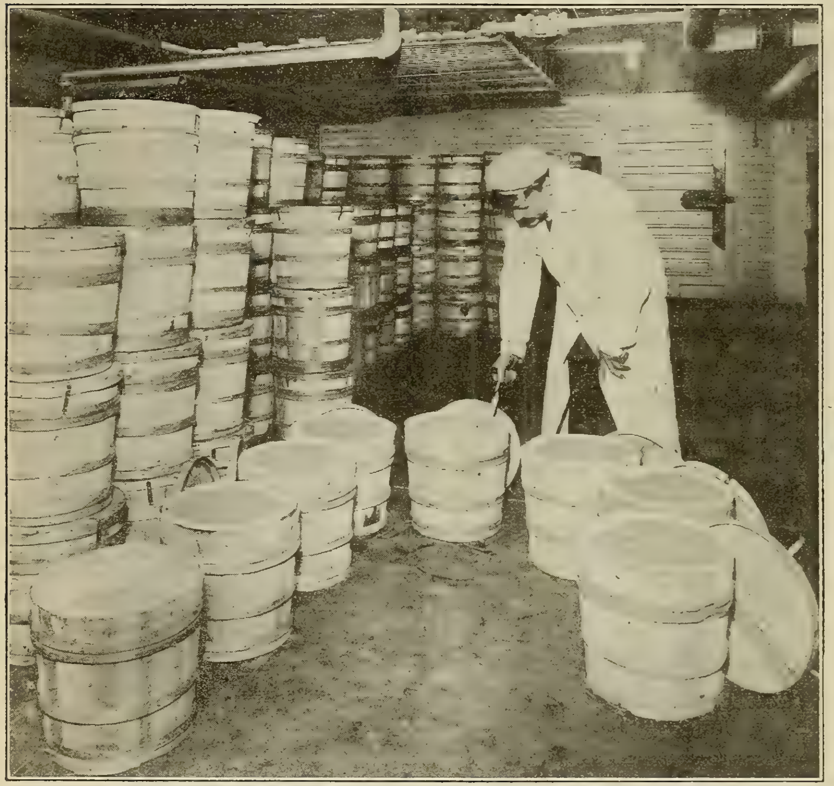

FIG. 5.—Inspecting a shipment of butter by a wholesale receiver.

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[1] Chain stores consist of a number of retail stores operated under a single management.

CONCLUSIONS.

The great majority of the creameries in Wisconsin and Minnesota usually produced a quality of butter for which there was an active market demand. The comparative ease with which creameries have been able to contract, or to sell their butter to wholesale receivers has not necessitated the employment of expert salesmanship. With traveling representatives of wholesale receivers willing to contract for the yearly output of the creameries and the contracts with receivers frequently renewed year after year, individual rather than cooperative action among creameries in marketing butter has prevailed. In most instances the creameries have been well satisfied with the returns received and therefore the necessity of cooperation among creameries has not been strongly apparent. Thus the efforts toward organizing cooperative marketing federations of creameries for marketing butter independent of the regular wholesale outlets, have never found much favor or been developed to any great extent.

The need for cooperative action among creameries in marketing their butter, and the advantages to be derived therefrom in the future, will depend upon the changes which take place in the market distribution and the butter marketing conditions in the larger wholesale markets. The present increasing demand for manufacturers' brands and for carload shipments of butter of uniform quality, indicates a growing change in marketing conditions, and suggests the need of cooperation among country creameries in standardizing the quality of their butter in accordance with such requirements as those of "State brands,"[1] and of being better informed regarding market conditions and outlets for the sale and distribution of their product. It is possible that the benefits to be derived by cooperative action and through marketing federations of creameries may be more apparent in the future than in the past, as improved marketing methods are required to meet the problems which may arise under new marketing conditions.

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[1] The requirements of State brands in Minnesota, Michigan, and Iowa are given in Bulletin No. 456 of the U. S. Department of Agriculture, entitled "Marketing Creamery Butter."

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 691

Contribution from the Office of Public Roads and Rural Engineering, LOGAN WALLER PAGE, Director

WASHINGTON, D. C. ▼ **July 10, 1918**

TYPICAL SPECIFICATIONS FOR BITUMINOUS ROAD MATERIALS.

By PRÉVOST HUBBARD, *Chemical Engineer*, and CHARES S. REEVE, *Chemist*.

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INTRODUCTION.

Since public attention was first attracted to the use of bituminous materials in road treatment and construction the Office of Public Roads and Rural Engineering has received increasingly numerous requests for specifications which will describe suitable types and grades of such materials for the various uses required in highway engineering. It was early realized that the preparation of standard specifications of any value would be extremely difficult if not impossible, owing to the widely varying characteristics of the materials which should be covered and to the many local factors, such as climate, traffic, and character of available non-bituminous road material, which largely control service results and which should govern the selection of suitable bituminous material. Therefore, attempts were first made to consider every request as an individual problem and to furnish specifications only after certain information relative to local conditions and proposed methods of treatment or construction had been secured.

Gradually, as the result of its own experimental work as well as observation of the work of others, the Office was able to prepare certain specifications which though not considered as standards were found to be in most cases serviceable for general use in well established types of construction and maintenance. Such specifications were called typical specifications and were furnished, upon request, on typewritten or mimeographed sheets. As additional information was secured, new methods of use devised, and the character of available crude materials and their method of refining changed, these typical specifications were modified from time to time by the Office. Owing to the fact that they are widely distributed among engineers not in close touch with the reasons necessitating their modification, certain of the older specifications are still in use, although not up to date. In so far as possible these engineers have been notified of changes which the Office has seen fit to make, but as, in many cases, the originals have been passed on from one engineer to another all have not been informed of the changes which have been made.

Very recently all of the typical specifications for bituminous materials prepared by the Office have been revised, and it has been considered advisable to publish them in bulletin form for more general distribution. The specifications given in the following pages, therefore, are intended to supersede all prior specifications for bituminous materials issued by the Office. It is felt that these revised specifications have been made as brief and simple as possible without sacrificing to too great an extent three essential purposes, which are (1) to secure a suitable grade of material, (2) to insure reasonable uniformity of supply, and (3) to sufficiently identify the material by type.

No specification should be encumbered with unnecessary requirements, and test limits, of course, should be thoroughly practicable from a manufacturing standpoint. With this in mind the cooperation of all manufacturers of bituminous road materials was sought. In July, 1917, a set of tentative revised specifications was sent to all manufacturers who were thought to be interested, with a request that they review the specifications, suggest changes if they so desired, and state the reasons for such suggested change. In addition the manufacturers were requested to furnish to the office samples of each of their products which conformed to the specifications, together with samples of any products which would meet the specifications if changed in accordance with their suggestions.

Upon receipt of all of the information that could be secured, the comments of the manufacturers were tabulated, together with the test results which they furnished and the analyses of the samples examined in the laboratory of the office. These data were carefully studied and when justified, modifications were made in the tentative specifications which in their revised form are presented in this bulletin. The forms of specification adopted are in general those recommended by the first conference of State Highway Testing Engineers and Chemists.[1]

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[1] U. S. Department of Agriculture Bulletin 555.

The specifications appearing in the following pages are grouped according to type of material, as shown in the detailed table of contents. A special index, however, is given for the convenience of engineers interested in materials suitable for particular methods of use or types of construction. Following each specification is a brief paragraph stating the purpose for which the material is intended, its method of use, the type of road, and general conditions for which it is suited, and the results which may be expected if it is properly used.

This information is necessarily general in character and should not be interpreted too rigidly. Varying combinations of climate, traffic, and character of the nonbituminous portion of the road which can not be discussed in a single paragraph will often influence the selection of the bituminous material and its method of use. More detailed information and advice relating to their use in maintenance and construction may be obtained upon application to the office.

It is realized that all classes and types of bituminous materials have not been covered and it is intended to add to the number of these specifications from time to time as additional information is obtained. In the meantime they are offered more as a guide and help to those engineers who are not thoroughly familiar with the characteristics of bituminous materials rather than as a substitute for specifications now in use which have already demonstrated their value in securing the material which is desired. It is realized that the same material is often described by two entirely different sets of tests and test limits, so that the same ultimate result may be obtained by two different specifications. Unfortunately different methods of specifying bituminous materials are followed by various highway engineers and commissions, and it would appear highly desirable that uniform practice in this matter be generally adopted. It is hoped that the typical specifications here given may further such practice, in the interests of both consumer and producer.

For the convenience of engineers and in order to make this bulletin complete in itself the methods of test to which reference is made in the specifications, and directions for sampling are included in this bulletin.

SPECIFICATIONS.

OC-1. PETROLEUM PRODUCT FOR DUST PALLIATIVE.

General. The petroleum product shall be homogeneous and free from water.

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.) -- not more than 0.940
2. Flash point ---------------- not less than 100° C. (212° F.)
3. Specific viscosity at 25° C. (77° F.) ------ not more than 10
4. Loss at 163° C. (325° F.), 5 hours ------ not more than 15%
   - *a.* Float test of residue at 32° C. (89.6° F.) -------- liquid
5. Total bitumen (soluble in carbon disulphide), not less than 99.8%

Methods of testing. Tests of the physical and chemical properties of the petroleum product shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 4.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Specific viscosity (on first 50 c. c.), U. S. Department of Agriculture Bulletin 314, p. 7.
4. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19.
   - *a.* Float test, U. S. Department of Agriculture Bulletin 314, p. 9.
5. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides primarily for a material to be used as a dust palliative on macadam, shell, gravel, or well compacted earth or sand-clay roads. It is not expected to build up a bituminous mat on the road surface, as materials meeting this specification are deficient in binding value. The specification is intended to cover some crude petroleums, heavy petroleum distillates, and light fluid residual petroleums.

To obtain the best results the road surface should be free of any great excess of dust when the application is made. The oil may be applied without heating and the application should preferably be made by means of a pressure distributor at the rate of from one-eighth to one-fourth of a gallon per square yard. No cover of earth, sand, gravel, or stone chips should be necessary. The number of applications required to lay the dust successfully throughout an entire season will depend upon traffic and climatic conditions; one may prove sufficient, but three or four may be required.

OC–2. ROAD OIL FOR COLD APPLICATION.

General.

The road oil shall be homogeneous and free from water.

Physical and chemical properties.

It shall meet the following requirements:

1. Specific gravity 25°/25°C. (77°/77°F.)---- 0.935 to 0.970
2. Fash point----------------not more than 50°C. (122°F.)
3. Specific viscosity at 25°C. (77°F.)--------------80 to 120
4. Loss at 163°C. (325°F.), 5 hours------not more than 30%
    a. Float test of residue at 50° C. (122° F.), not less than 90 sec.
5. Total bitumen (soluble in carbon disulphide), not less than 99.5%
6. Per cent of total bitumen insoluble in 86°B. naphtha, not less than 6.0%

Methods of testing.

Tests of the physical and chemical properties of the road oil shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 4.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Specific viscosity (on first 50 c.c.), U. S. Department of Agriculture Bulletin 314, p. 7.
4. Volatilization test (loss at 163°C.), U. S. Department of Agriculture Bulletin 314, p. 19.
    a. Float test. U. S. Department of Agriculture Bulletin 314, p. 9.
5. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.
6. Bitumen insoluble in naphtha, U. S. Department of Agriculture Bulletin 314, p. 28.

This specification provides primarily for a material to be used in the cold surface treatment of macadam or shell roads to form a thin wearing mat or carpet which may be maintained or built up by subsequent treatments of either the same type of material or a heavier product (specification OH–1). The specification is intended to cover certain types of crude or topped petroleums and cut-back oil asphalts.

A successful treatment requires that the road surface shall be in a good state of repair, well consolidated, free from holes or depressions, and thoroughly swept for the removal of dust and detritus before the application is made. Newly constructed roads should be permitted to consolidate under traffic before the oil is applied. The oil may be applied without heating, and the initial applications should be made by means of a pressure distributer at the rate of from one-third to one-half a gallon per square yard. It should be covered with a uniform layer of dustless broken stone, all of which will pass a one-half or three-fourths-inch laboratory screen, or with pea gravel, which will pass a one-half-inch laboratory screen in an amount just sufficient to absorb the bitumen and to prevent the surface from picking up under traffic. Subsequent applications may be made by a pressure distributer or by brooming the oil uniformly over the road surface. From one-tenth to one-fifth gallon per square yard will usually prove sufficient, and this should be covered with coarse sand or stone clips which will pass a one-inch laboratory screen.

To secure best results the treatment should be applied in the early summer, excepting in localities where snow and freezing weather are not common. Under favorable conditions a treatment should last throughout at least one season.

OH-1. ROAD OIL FOR HOT APPLICATION.

General.

The road oil shall be homogenous, free from water, and shall not foam when heated to 120° C. (248° F.)

Physical and chemical properties.

It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.), not less than 0.980
2. Flash point________________not less than 80° C. (176° F.)
3. Specific viscosity 100° C. (212° F.)_______not more than 60
4. Float test at 32° C. (89.6° F.)________not less than 60 sec.
5. Loss at 163° C. (325° F.), 5 hours_____not more than 15%
   - *a.* Float test of residue 50° C. (122° F.), not less than 110 sec.
6. Total bitumen (soluble in carbon disulphide), not less than 99.5%
7. Per cent of total bitumen insoluble in 86° B. naptha, not less than 6.0%

Methods of testing.

Tests of the physical and chemical properties of the road oil shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Specific viscosity (on first 50 c. c), U. S. Department of Agriculture Bulletin 314, p. 7.
4. Float test, U. S. Department of Agriculture Bulletin 314, p. 9.
5. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.
7. Bitumen insoluble in naphtha, U. S. Department of Agriculture Bulletin 314, p. 28.

This specification provides primarily for a material to be used in the hot surface treatment of macadam, gravel, or shell roads, to form a wearing mat or carpet. The specification is intended to cover residual asphaltic petroleums, cut-back oil asphalts, and some crude asphaltic petroleums.

A successful treatment requires that the road surface shall be in a good state of repair, well consolidated, free from holes or depressions, and thoroughly swept for the removal of dust and detritus before the application is made. Newly constructed or resurfaced roads should be permitted to consolidate under traffic before the oil is applied. The oil should be heated to a temperature of 200° F to 250° F. before applying, and the application should be made by means of a pressure distributor at the rate of from one-third to one-half gallon per square yard. It should be covered with a uniform layer of dustless broken stone all of which will pass a one-inch or three-fourths inch laboratory screen or pea gravel which will pass a one-half inch laboratory screen in an amount just sufficient to absorb the bitumen and to prevent the surface from picking up under traffic. Subsequent applications may be made by a pressure distributor or by brooming the oil uniformly over the road surface. From one-tenth to one-fifth gallon per square yard will usually prove sufficient, and this should be covered with coarse sand or stone chips which will pass a one-half inch laboratory screen. To obtain best results the treatment should be applied in the early summer except in localities where snow and freezing weather are not common. Under favorable conditions with occasional patching of any breaks in the surface a treatment should last for several years.

OA-1. OIL ASPHALT FOR CONSTRUCTION.

General. The oil asphalt shall be homogeneous, free from water, and shall not foam when heated to 175° C. (347° F.).

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.)-not less than 1.000
2. Flash point——————not less than 175° C. (347° F.)
3. Melting point—————35° C. (95° F.) to 55° C. (131° F.)
4. Penetration at 25° C. (77° F.), 100 g., 5 sec.——120 to 150
5. Loss at 163° C. (325° F.) 5 hours——not more than 1.0%
   a. Penetration of residue at 25° C. (77° F.), 100 g., 5 sec.——————————not less than 70
6. Total bitumen (soluble in carbon disulphide)—————not less than 99.5%
   a. Organic matter insoluble—————not more than 0.2%

NOTE.—Material for any one contract shall not vary more than 0.020 in specific gravity nor more than 10° C. in melting point within the test limits above specified.

Methods of testing. Tests of the physical and chemical properties of the oil asphalt shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Melting point, A. S. T. M. Tentative Standard D 36–16 T, Proceedings A. S. T. M. 1916, p. 549.
4. Penetration, A. S. T. M. Standard Test D 5–16.
5. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19, using 50 gram sample.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of bituminous macadam in the northern United States. It is intended to cover satisfactory grades of oil asphalts prepared from Mexican, California, Texas, and other petroleums.

It should be applied at a temperature of from 275° F. to 350° F. to the upper or wearing course of compacted broken stone at the rate of from 1½ to 1¾ gallons per square yard. The application may be made by means of pouring pots or by a pressure distributor so designed that it will not produce ruts during application. The above quantities are based on a wearing course 3 inches in thickness before rolling, composed of a product which will pass a 2 to 3-inch laboratory screen and be retained on a 1-inch laboratory screen. The exact range in size should be governed by the kind and quality of rock used. The application should be followed by a sufficient amount of clean small sized broken stone to fill the surface voids when thoroughly rolled. A seal coat of the hot asphalt should then be applied at the rate of 0.4 to 0.6 gallon per square yard and covered with a sufficient amount of stone chips to just absorb the excess bitumen. Roads of this character may be maintained with oil surface treatments using the materials and methods given under specifications OC–2 or OH–1. The latter is usually to be preferred. Such maintenance treatments should be applied whenever the wear comes directly upon the wearing course rock.

OA-2. OIL ASPHALT FOR CONSTRUCTION.

General.

The oil asphalt shall be homogeneous, free from water, and shall not foam when heated to 175° C. (347° F.)

Physical and chemical properties.

It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.)--not less than 1.000
2. Flash point----------------not less than 175° C. (347° F.)
3. Melting point-----------35° C. (95° F.) to 55° C. (131° F.)
4. Penetration at 25° C. (77° F.), 100 g., 5 sec-------90 to 120
5. Loss at 163° C. (325° F.) 5 hours------not more than 1.0%
   a. Penetration of residue at 25° C. (77° F.), 100 g., 5 sec--------------------------------not less than 60
6. Total bitumen (soluble in carbon disulphide), not less than 99.5%
   a. Organic matter insoluble-----------not less than 0.2%

NOTE.—Material for any one contract shall not vary more than 0.020 in specific gravity nor more than 10° C. in melting point within the test limits above specified.

Methods of testing.

Tests of the physical and chemical properties of the oil asphalt shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Melting point, A. S. T. M. Tentative Standard D 36-16 T. Proceedings A. S. T. M. 1916, p. 549.
4. Penetration, A. S. T. M. Standard Test D 5-16.
5. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19, using 50-gram sample.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of bituminous macadam in the middle belt of the United States. It is intended to cover satisfactory grades of oil asphalts prepared from Mexican, California, Texas, and other petroleums.

It should be applied at a temperature of from 300° F. to 350° F. to the upper or wearing course of compacted broken stone at the rate of from 1½ to 1¾ gallons per square yard. The application may be made by means of pouring pots or by a pressure distributor so designed that it will not produce ruts during application. The above quantities are based on a wearing course 3 inches in thickness before rolling, composed of a product which will pass a 2 to 3 inch laboratory screen and be retained on a 1-inch laboratory screen. The exact range in size should be governed by the kind and quality of rock used. The application should be followed by a sufficient amount of clean small-sized broken stone to fill the surface voids when thoroughly rolled. A seal coat of the hot asphalt should then be applied at the rate of 0.4 to 0.6 gallon per square yard and covered with a sufficient amount of stone chips to just absorb the excess bitumen. Roads of this character may be maintained with oil surface treatments, using the materials and methods given under specifications OC–2 or OH–1. The latter is usually to be preferred. Such maintenance treatments should be applied whenever the wear comes directly upon the wearing course rock.

OA-3. OIL ASPHALT FOR CONSTRUCTION.

General.

The oil asphalt shall be homogeneous, free from water, and shall not foam when heated to 175° C. (347° F.).

Physical and chemical properties.

It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.) not less than 1.010
2. Flash point not less than 175° C. (347° F.)
3. Melting point 40° C. (104° F.) to 60° C. (140° F.)
4. Penetration at 25° C. (77° F.), 100 g., 5 sec 80 to 90
5. Loss at 163° C. (325° F.) 5 hours not more than 1.0%
   - *a.* Penetration of residue at 25° C. (77° F.), 100 g., 5 sec not less than 50
6. Total bitumen (soluble in carbon disulphide), not less than 99.5%
   - *a.* Organic matter insoluble not more than 0.2%

NOTE.—Material for any one contract shall not vary more than 0.020 in specific gravity nor more than 10° C. in melting point within the test limits above specified.

Methods of testing.

Tests of the physical and chemical properties of the oil asphalt shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Melting point, A. S. T. M. Tentative Standard D-36-16 T. Proceedings A. S. T. M. 1916, p. 549.
4. Penetration, A. S. T. M. Standard Test D 5-16.
5. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19, using 50 gram sample.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of bituminous macadam in the southern United States or for one size stone bituminous concrete in the northern United States. It is intended to cover satisfactory grades of oil asphalts prepared from Mexican, California, Texas, and other petroleums.

In bituminous macadam construction it should be applied in the manner outlined under Specification OA-2.

One size stone bituminous concrete contemplates a mixture of the asphalt with a crusher product passing a 1¾-inch screen and retained upon a half-inch screen. The asphalt should be heated to a temperature of from 275° F. to 325° F. and the crushed stone to a temperature of from 150° F. to 250° F. before mixing. The mixture should contain from 5 per cent to 7 per cent bitumen. The hot mixture should be deposited in a uniform layer over a concrete or well-compacted broken stone or gravel foundation to such depth that it will yield a uniform layer two inches in thickness after thorough rolling. A seal coat of the hot asphalt should then be applied at the rate of 0.4 to 0.6 gallon per square yard and covered with a sufficient amount of stone chips to just absorb the excess bitumen. Roads of this character may be maintained with oil-surface treatments using the materials and methods given under specifications OC–2 or OH–1. The latter is usually to be preferred. Such maintenance treatments should be applied whenever the wear comes directly upon the wearing course rock.

OA-4. OIL ASPHALT FOR CONSTRUCTION.

General. The oil asphalt shall be homogeneous, free from water, and shall not foam when heated to 175° C. (347° F.).

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.), not less than 1.010
2. Flash point ---------------- not less than 175° C. (347° F.)
3. Melting point ---------- 40° C. (104° F.) to 60° C. (140° F.)
4. Penetration at 25° C. (77° F.) 100 g., 5 sec --------- 70 to 80
5. Loss at 163° C. (325° F.) 5 hours ------- not more than 1.0%
   - *a.* Penetration of residue at 25° C. (77° F.), 100 g., 5 sec ------------------------------ not less than 45
6. Total bitumen (soluble in carbon disulphide), not less than 99.5%
   - *a.* Organic matter insoluble ---------- not more than 0.2%

NOTE.—Material for any one contract shall not vary more than 0.020 in specific gravity nor more than 10° C. in melting point within the test limits above specified.

Methods of testing. Tests of the physical and chemical properties of the oil asphalt shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Melting point, A. S. T. M. Tentative Standard D 36-16 T, Proceedings A. S. T. M. 1916, p. 549.
4. Penetration, A. S. T. M. Standard Test D 5-16.
5. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19, using 50-gram sample.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of one size stone bituminous concrete in the southern United States or of graded coarse aggregate bituminous concrete in the northern United States. It is intended to cover satisfactory grades of oil asphalts prepared from Mexican, California, Texas, and other petroleums.

In one size stone bituminous concrete construction it should be used in the manner outlined under Specification OA-3.

Graded coarse aggregate bituminous concrete contemplates a mixture of the oil asphalt with crushed stone or a mixture of crushed stone and sand well graded in size from particles approximately one-half the thickness of the wearing course to dust. The asphalt should be heated to a temperature of from 275° F., to

325° F., and the mineral aggregate to a temperature of from 250° F., to 300° F., before mixing. The mixture should contain from 6% to 8% bitumen, and will vary within these limits with the character of the rock and the exact grading of the aggregate. The hot mixture should be deposited in a uniform layer over a concrete or well compacted broken stone or gravel foundation to such depth that it will yield a uniform layer 2 to 2½ inches in thickness after thorough rolling. A seal coat of the hot oil asphalt should then be applied at the rate of 0.4 to 0.6 gallon per square yard and covered with a sufficient amount of stone chips to just absorb the excess bitumen. Roads of this character may be maintained with oil surface treatments using the materials and methods given under Specifications OC–2 or OH–1. The latter is usually to be preferred. Such maintenance treatments should be applied whenever the wear comes directly upon the wearing course rock.

OA-5. OIL ASPHALT FOR CONSTRUCTION.

General.

The oil asphalt shall be homogeneous, free from water, and shall not foam when heated to 175° C. (347° F.).

Physical and chemical properties.

It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.)-not less than 1.010
2. Flash point----------------not less than 175° C. (347° F.)
3. Melting point----------40° C. (104° F.) to 60° C. (140° F.)
4. Penetration at 25° C. (77° F.), 100 g., 5 sec-------60 to 70
5. Loss at 163° C. (325° F.), 5 hours------not more than 1.0%
    a. Penetration of residue at 25° C. (77° F.) 100 g., 5 sec-----------------------------------not less than 40
6. Total bitumen (soluble in carbon disulphide), not less than 99.5%
    a. Organic matter insoluble---------not more than 0.2%

NOTE.—Material for any one contract shall not vary more than 0.020 in specific gravity nor more than 10° C. in melting point within the test limits above specified.

Methods of testing.

Tests of the physical and chemical properties of the oil asphalt shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Melting point, A. S. T. M. Tentative Standard D 36-16 T, Proceedings A. S. T. M. 1916, p. 549.
4. Penetration, A. S. T. M. Standard Test D 5-16.
5. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19, using 50 gram sample.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of graded coarse aggregate bituminous concrete in the southern United States or for graded fine aggregate bituminous concrete in the northern United States. It is intended to cover satisfactory grades of oil asphalts prepared from Mexican, California, Texas, and other petroleums.

In graded coarse aggregate bituminous concrete construction it should be used in the manner outlined under Specification OA-4.

Graded fine aggregate bituminous concrete contemplates a mixture of the oil asphalt with crushed stone or a mixture of crushed stone and sand well graded in size from particles that will pass a one-half-inch laboratory screen to dust such as the "Topeka" type of pavement with its modifications. The asphalt should be heated to a temperature of from 275° F. to 325° F. and the mineral aggregate to a temperature of from 250° F. to 300° F. before mixing. The mixture should contain from 7 per cent to 11 per cent bitumen and will vary within these limits with the character of the rock and the exact grading of the aggregate. The hot mixture should be deposited in a uniform layer over a concrete or well compacted broken stone or gravel foundation to such depth that it will yield a uniform layer 2 inches in thickness after thorough rolling. A seal coat should not be necessary on this type of pavement, which is usually maintained by patching with the same mixture used in construction.

OA-6. OIL ASPHALT FOR CONSTRUCTION.

General.

The oil asphalt shall be homogeneous, free from water and shall not foam when heated to 175° C. (347° F.).

Physical and chemical properties.

It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.), not less than 1.020
2. Flash point________________not less than 175° C. (347° F.)
3. Melting point_________40° C. (104° F.) to 60° C. (140° F.)
4. Penetration at 25° C. (77° F.), 100 g., 5 sec________50 to 60
5. Loss at 163° C. (325° F.) 5 hours______not more than 1.0%
    a. Penetration of residue at 25° C. (77° F.) 100 g., 5 sec______________________________not less than 30
6. Total bitumen (soluble in carbon disulphide), not less than 99.5%
    a. Organic matter insoluble__________not more than 0.2%

NOTE.—Material for any one contract shall not vary more than 0.020 in specific gravity nor more than 10° C. in melting point within the test limits above specified.

Methods of testing.

Tests of the physical and chemical properties of the oil asphalt shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cup), U. S. Department of Argiculture Bulletin 314, p. 17.
3. Melting point, A. S. T. M. Tentative Standard D 36–16–T, Proceedings A. S. T. M., 1916, p. 549.
4. Penetration, A. S. T. M. Standard Test D 5–16.
5. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19, using 50 gram sample.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of graded fine aggregate bituminous concrete in the southern United States or for sheet asphalt construction in the northern United States. It may also be used as a seal coat on tar macadam or tar concrete roads. It is intended to cover satisfactory grades of oil asphalt prepared from Mexican, California, Texas, and other petroleums.

In fine aggregate bituminous concrete construction it should be used in the manner outlined under specification OA–5.

Sheet asphalt construction contemplates a mixture of the oil asphalt with properly graded sand and a mineral filler. The asphalt and sand should be heated separately to a temperature of from 275° F. to 325° F. The filler should be added to the hot sand and followed by the asphalt. The mixture should contain from 9 per cent to 12 per cent bitumen and will vary within these limits with the exact grading of the aggregate. After thorough mixing the hot mixture should be deposited in a uniform layer on a binder course which has been previously laid over a concrete base. It should be laid to such depth that it will yield a uniform layer 1½ or 2 inches in thickness as may be required after thorough rolling.

As a seal coat for tar macadam or tar concrete roads it is applied during construction of the road at a temperature of from 300° F. to 350° F. It is used as a substitute for tar seal coat and may be applied at the same rate and covered in the same manner as described under Specifications TP–2 and TP–3.

OA-7. OIL ASPHALT FOR CONSTRUCTION.

General. The oil asphalt shall be homogeneous, free from water, and shall not foam when heated to 175° C. (347° F.).

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.)__not less than 1.020
2. Flash point________________not less than 175° C. (347° F.)
3. Melting point_________45° C. (113° F.) to 65° C. (149° F.
4. Penetration at 25° C. (77° F.), 100 g., 5 sec______40 to 50
5. Loss at 163° C. (325° F.) 5 hours____not more than 1.0%
    a. Penetration of residue at 25° C. (77° F.), 100 g., 5 sec_____________________________not less than 25
6. Total bitumen (soluble in carbon disulphide), not less than 99.5%
    a. Organic matter insoluble_________not more than 0.2%

NOTE.—Material for any one contract shall not vary more than 0.020 in specific gravity nor more than 10° C. in melting point within the test limits above specified.

Methods of testing. Tests of the physical and chemical properties of the oil asphalt shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Melting point, A. S. T. M. Tentative Standard D 36–16 T, Proceedings A. S. T. M., 1916, p. 549.
4. Penetration, A. S. T. M. Standard Test D 5–16.
5. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19, using 50 gram sample.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used for sheet asphalt construction in the southern United States or for the same type of construction in the northern United States to withstand very heavy traffic. It is intended to cover satisfactory grades of oil asphalts prepared from Mexican, California, Texas, and other petroleums.

Sheet asphalt construction contemplates a mixture of the oil asphalt with properly graded sand and a mineral filler. The asphalt and sand should be heated separately to a temperature of from 275° F. to 325° F. The filler should be added to the hot sand and followed by the asphalt. The mixture should contain from 9 per cent to 12 per cent bitumen and will vary within these limits with the exact grading of the aggregate. After thorough mixing the hot mixture should be deposited in a uniform layer on a binder course which has been previously laid over a concrete base. It should be laid to such depth that it will yield a uniform layer 1½ or 2 inches in thickness as may be required after thorough rolling.

OAF-1. OIL ASPHALT FOR POURED-JOINT FILLER.

General. The oil asphalt shall be homogeneous, free from water, and shall not foam when heated to 200° C. (392° F.).

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.), not less than 0.980
2. Flash point---------------not less than 200° C. (392° F.)
3. Melting point-------------not less than 80° C. (172° F.)
4. Penetration at 25° C. (77° F.), 100 g., 5 sec---------30 to 50
   Penetration at 0° C. (32° F.), 200 g., 1 min., not less than 20
   Penetration at 46.1° C. (115° F.), 50 g., 1 sec., not more than 100
5. Loss at 163° C. (325° F.), 5 hours-----not more than 1.0%
   Penetration of residue at 25° C. (77° F.), 100 g., 5 sec., not less than 20
6. Total bitumen (soluble in carbon disulphide), not less than 99.5%
   a. Organic matter insoluble--------not more than 0.2%

Methods of testing. Tests of the physical and chemical properties of the oil asphalt shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Melting point, A. S. T. M. Tentative Standard D 36-16 T, Proceedings A. S. T. M. 1916, p. 549.
4. Penetration, A. S. T. M. Standard Test D 5-16.
5. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19, using 50 gram sample.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for an oil asphalt filler to be used in filling the joints of brick or stone block pavements. It may also be used to fill expansion joints.

All of the longitudinal and transverse joints between the brick should, when clean and dry, be completely filled with the bituminous filler heated to a temperature of not less than 350° F., nor more than 400° F., as directed. The filler should preferably be applied by means of pouring cans provided with a conical outlet and means for the control of the flow of filler. A top dressing of clean dry sand should be spread immediately after the filler is applied.

NA-1. FLUXED BERMUDEZ ASPHALT FOR CONSTRUCTION.

General.

The fluxed native asphalt shall be homogenous, free from water, and shall not foam when heated to 175° C. (347° F.).

Physical and chemical properties.

It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.)------1.025 to 1.050
2. Flash point-----------------not less than 175° C. (347° F.)
3. Melting point-----------35° C. (95° F.) to 45° C. (113° F.)
4. Penetration at 25° C. (77° F.) 100 g., 5 sec------120 to 150
5. Loss at 163° C. (325° F.), 5 hours-----not more than 3.0%
    - *a.* Penetration of residue at 25° C. (77° F.), 100 g., 5 sec. not less than 60
6. Total bitumen (soluble in carbon disulphide), not less than 95.0%
    - *b.* Inorganic matter insoluble--------------1.5% to 2.5%

Methods of testing.

Tests of the physical and chemical properties of the fluxed native asphalt shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Melting point, A. S. T. M. Tentative Standard D 36–16 T. Proc. A. S. T. M. 1916, p. 549.
4. Penetration, A. S. T. M. Standard Test D 5–16.
5. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19, using 50-gram sample.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of bituminous macadam in the northern United States. It is intended to cover satisfactory grades of products prepared by fluxing Bermudez asphalt.

It should be applied at a temperature of from 275° F., to 350° F., to the upper or wearing course of compacted broken stone at the rate of from 1½ to 1¾ gallons per square yard. The application may be made by means of pouring pots or by a pressure distributor so designed that it will not produce ruts during application. The above quantities are based on a wearing course 3 inches in thickness before rolling, composed of a product which will at least pass a 3-inch laboratory screen and be retained on a 1-inch laboratory screen. The exact range in size should be governed by the kind and quality of rock used. The application should be followed by a sufficient amount of clean small sized broken stone to fill the surface voids when thoroughly rolled. A seal coat of the same bituminous material should then be applied at the rate of 0.4 to 0.6 gallon per square yard and covered with a sufficient amount of stone chips to just absorb the excess bitumen. Roads of this character may be maintained with oil surface treatments using the materials and methods given under Specification OC–2 or OH–1. Such maintenance treatments should be applied whenever the wear comes directly upon the wearing course rock.

NA-2. FLUXED BERMUDEZ ASPHALT FOR CONSTRUCTION.

General. The fluxed native asphalt shall be homogeneous, free from water, and shall not foam when heated to 175° C. (347° F.)

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.)______1.030 to 1.050
2. Flash point_______________not less than 175° C. (347° F.)
3. Melting point_________40° C. (104° F.) to 50° C. (122° F.)
4. Penetration at 25° C. (77° F.), 100 g., 5 sec______90 to 120
5. Loss at 163° C. (325° F.), 5 hours____not more than 3.0%
    a. Penetration of residue at 25° C. (77° F.), 100 g., 5 sec______________________________not less than 45
6. Total bitumen (soluble in carbon disulphide), not less than 95.0%
    b. Inorganic matter insoluble_____________1.5% to 2.5%

Methods of testing. Tests of the physical and chemical properties of the fluxed native asphalt shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Melting point, A. S. T. M. Tentative Standard D 36-16 T. Proc. A. S. T. M. 1916, p. 549.
4. Penetration, A. S. T. M. Standard Test D 5-16.
5. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19, using 50 gram sample.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of bituminous macadam in the middle belt of the United States. It is intended to cover satisfactory grades of products prepared by fluxing Bermudez asphalt.

It should be applied at a temperature of from 300° F. to 350° F., to the upper or wearing course of compacted broken stone at the rate of from 1½ to 1¾ gallons per square yard. The application may be made by means of pouring pots or by a pressure distributor so designed that it will not produce ruts during application. The above quantities are based on a wearing course 3 inches in thickness before rolling, composed of a product which will at least pass a 3-inch laboratory screen and be retained on a 1-inch laboratory screen. The exact range in size should be governed by the kind and quality of rock used. The application should be followed by a sufficient amount of clean small sized broken stone to fill the surface voids when thoroughly rolled. A seal coat of the same bituminous material should then be applied at the rate of 0.4 to 0.6 gallon per square yard and covered with a sufficient amount of stone chips to just absorb the excess bitumen. Roads of this character may be maintained with oil surface treatments using the materials and the methods given under specifications OC–2 or OH–1. The latter is usually to be preferred. Such maintenance treatments should be applied whenever the wear comes directly upon the wearing course rock.

NA–3. FLUXED BERMUDEZ ASPHALT FOR CONSTRUCTION.

General.

The fluxed native asphalt shall be homogeneous, free from water, and shall not foam when heated to 175° C. (347° F.).

Physical and chemical properties.

It shall meet the following requirements:

1. Specific gravity, 25°/25° C. (77°/77° F.)------1.050 to 1.070
2. Flash point----------------not less than 175° C. (347° F.)
3. Melting point----------40° C. (104° F.) to 50° C. (122° F.)
4. Penetration at 25° C. (77° F.), 100 g., 5 sec---------80 to 90
5. Loss at 163° C. (325° F.), 5 hours-------not more than 3.0%
    a. Penetration of residue at 25° C. (77° F.), 100 g., 5 sec----------------------------------not less than 40
6. Total bitumen (soluble in carbon disulphide), not less than 95.0%
    b. Inorganic matter insoluble---------------1.5% to 3.0%

Methods of testing.

Tests of the physical and chemical properties of the fluxed native asphalt shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Melting point, A. S. T. M. Tentative Standard D 36–16 T. Proc. A. S. T. M. 1916, p. 549.
4. Penetration, A. S. T. M. Standard Test D 5–16.
5. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19, using 50-gram sample.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of bituminous macadam in the southern United States, or for one size stone bituminous concrete in the northern United States. It is intended to cover satisfactory grades of products prepared by fluxing Bermudez asphalt.

In bituminous macadam construction it should be applied in the manner outlined under Specification NA–2.

One size stone bituminous concrete contemplates a mixture of the fluxed asphalt with a crusher product passing a 1¼-inch screen and retained upon a one-half inch screen. The bituminous material should be heated to a temperature of from 275° F. to 325° F., and the crushed stone to a temperature of from 150° F. to 250° F., before mixing. The mixture should contain from 5% to 7% bitumen and will vary within these limits with the exact grading of the aggregate. The hot mixture should be deposited in a uniform layer over a concrete or well compacted broken stone or gravel foundation to such depth that it will yield a uniform layer 2 inches in thickness after thorough rolling. A seal coat of the same bituminous material should then be applied at the rate of 0.4 to 0.6 gallon per square yard and covered with a sufficient amount of stone chips to just absorb the excess bitumen. Roads of this character may be maintained with oil surface treatments using the materials and methods given under Specifications OC–2 or OH–1. The latter is usually to be preferred. Such maintenance treatments should be applied whenever the wear comes directly upon the wearing course rock.

NA-4. FLUXED BERMUDEZ ASPHALT FOR CONSTRUCTION.

General. The fluxed native asphalt shall be homogenous, free from water, and shall not foam when heated to 175° C. (347° F.)

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.)------1.050 to 1.070
2. Flash point----------------not less than 175° C. (347° F.)
3. Melting point-----------40° C (104° F) to 50° C. (122° F.)
4. Penetration at 25° C. (77° F.), 100 g. 5 sec---------70 to 80
5. Loss at 163° C. (325° F.), 5 hours------not more than 3.0%
   a. Penetration of residue at 25° C. (77° F.), 100 g., 5 sec--------------------------------not less than 35
6. Total bitumen (soluble in carbon disulphide), not less than 95.0%
   b. Inorganic matter insoluble--------------2.0% to 3.5%

Methods of testing. Tests of the physical and chemical properties of the fluxed native asphalt shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cut), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Melting point, A. S. T. M. Tentative Standard D36 16T., Proc. A. S. T. M. 1916, p. 549.
4. Penetration, A. S. T. M. Standard Test D5–16.
5. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19, using 50-gram sample.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of one size stone bituminous concrete in the southern United States or of graded coarse aggregate bituminous concrete in the northern United States. It is intended to cover satisfactory grades of products prepared by fluxing Bermudex asphalt.

In one size stone bituminous concrete construction it should be used in the manner outlined under Specification NA–3.

Graded coarse aggregate bituminous concrete contemplates a mixture of the fluxed asphalt with crushed stone or a mixture of crushed stone and sand, well graded in size, from particles approximately one-half the thickness of the wearing course to dust. The bituminous material should be heated to a temperature of from 275° F. to 325° F., and the mineral aggregate to a temperature of from 250° F. to 300° F. before mixing. The mixture should contain from 6 per cent to 8 per cent bitumen and will vary within these limits with the character of the rock and the exact grading of the aggregate. The hot mixture should be deposited in a uniform layer over a concrete or well compacted broken stone or gravel foundation to such depth that it will yield a uniform layer 2 inches in thickness after thorough rolling. A seal coat of the same bituminous material should then be applied at the rate of 0.4 to 0.6 gallon per square yard and covered with a sufficient amount of chips to just absorb the excess bitumen. Roads of this character may be maintained with oil surface treatments, using the materials and methods given under Specifications OC–2 or OH–1. The latter is usually to be preferred. Such maintenance treatments should be applied whenever the wear comes directly upon the wearing course rock.

NA-5. FLUXED BERMUDEZ ASPHALT FOR CONSTRUCTION.

General.

The fluxed native asphalt shall be homogeneous, free from water, and shall not foam when heated to 175° C. (347° F.).

Physical and chemical properties.

It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.)____1.050 to 1.070
2. Flash point_______________not less than 175° C. (347° F.)
3. Melting point__________45° C. (113° F.) to 55° C. (131° F.)
4. Penetration at 25° C. (77° F.), 100 g., 5 sec________60 to 70
5. Loss at 163° C. (325° F.), 5 hours____not more than 3.0%
    - *a.* Penetration of residue at 25° C. (77° F.), 100 g., 5 sec____________________________not less than 30
6. Total bitumen (soluble in carbon disulphide), not less than 94.5%.
    - *b.* Inorganic matter insoluble____________2.0% to 3.5%

Methods of testing.

Tests of the physical and chemical properties of the fluxed native asphalt shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Melting point, A. S. T. M. Tentative Standard D-36-16 T., Proc. A. S. T. M., 1916, p. 549.
4. Penetration, A. S. T. M. Standard Test D 5-16.
5. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19, using 50-gram sample.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of graded coarse aggregate bituminous concrete in the southern United States or of graded fine aggregate bituminous concrete in the northern United States. It is intended to cover satisfactory grades of products prepared by fluxing Bermudez asphalt.

In graded coarse aggregate bituminous concrete construction it should be used in the manner outlined under Specification NA-4.

Graded fine aggregate bituminous concrete contemplates a mixture of the fluxed asphalt with crushed stone or a mixture of crushed stone and sand well graded in size from particles that will pass a one-half-inch laboratory screen to dust such as the " Topeka " type of pavement with its modifications. The bituminous material should be heated to a temperature of from 275° F. to 325° F. and the mineral aggregate to a temperature of from

250° F. to 300° F. before mixing. The mixture should contain from 7 per cent to 11 per cent bitumen and will vary within these limits with the character of the rock and the exact grading of the aggregate. The hot mixture should be deposited in a uniform layer over a concrete or a well-compacted broken stone or gravel foundation to such depth that it will yield a uniform layer two inches in thickness after thorough rolling. A seal coat should not be necessary on this type of pavement, which is usually maintained by patching with the same mixture used in construction.

NA-6. FLUXED BERMUDEZ ASPHALT FOR CONSTRUCTION.

General. The fluxed native asphalt shall be homogeneous, free from water, and shall not foam when heated to 175° C. (347° F.).

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.)-----1.050 to 1.070
2. Flash point--------------not less than 175° C. (347° F.)
3. Melting point-------- 45° C. (113° F.) to 55° C. (131° F.)
4. Penetration at 25° C. (77° F.)., 100 g., 5 sec------50 to 60
5. Loss at 163° C. (325° F.), 5 hours----not more than 3.0%
   a. Penetration of residue at 25° C. (77° F.), 100 g., 5 sec---------------------------------not less than 25
6. Total bitumen (soluble in carbon disulphide), not less than 94.0%.
   b. Inorganic matter insoluble -------------2.5% to 4.0%

Methods of testing. Tests of the physical and chemical properties of the fluxed native asphalt shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Melting point, A. S. T. M. Tentative Standard D 36–16 T. Proc. A. S. T. M. 1916, p. 549.
4. Penetration, A. S. T. M. Standard Test D 5–16.
5. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19, using 50-gram sample.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of graded fine aggregate bituminous concrete in the southern United States or for sheet asphalt construction in the northern United States. It is intended to cover satisfactory grades of products prepared by fluxing Bermudez asphalt.

In fine aggregate bituminous concrete construction it should be used in the manner outlined under Specification NA–5.

Sheet asphalt construction contemplates a mixture of the fluxed asphalt with properly graded sand and a mineral filler. The bituminous material and sand should be heated separately to a temperature of from 275° F. to 325° F. The filler should be added to the hot sand and followed by the asphalt. The mixture should contain from 9 to 12 per cent bitumen and will vary within these limits with the exact grading of the aggregate. After thorough mixing the hot mixture should be deposited in a uniform layer on a binder course which has been previously laid over a concrete base. It should be laid to such depth that it will yield a uniform layer 1½ or 2 inches in thickness as may be required after thorough rolling.

NA-7. FLUXED BERMUDEZ ASPHALT FOR CONSTRUCTION.

General. The fluxed native asphalt shall be homogeneous, free from water, and shall not foam when heated to 175° C. (347° F.).

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.)----1.055 to 1.075
2. Flash point----------------not less than 175° C. (347° F.)
3. Melting point---------45° C. (113° F.) to 55° C. (131° F.)
4. Penetration at 25° C. (77° F.), 100 g., 5 sec---------40 to 50
5. Loss at 163° C. (325° F.), 5 hours-----not more than 3.0%
    a. Penetration of residue at 25° C. (77° F.), 100 g., 5 sec-------------------------------not less than 20
6. Total bitumen (soluble in carbon disulphide), not less than 94.0%
    b. Inorganic matter insoluble-------------2.5% to 4.0%

Methods of testing. Tests of the physical and chemical properties of the fluxed native asphalt shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Melting point, A. S. T. M. Tentative Standard D 36–16 T. Proc. A. S. T. M. 1916, p. 549.
4. Penetration, A. S. T. M. Standard Test D 5–16.
5. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19, using 50 gram sample.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used for sheet asphalt construction in the southern United States or for the same type of construction in the northern United States to withstand very heavy traffic. It is intended to cover satisfactory grades of products prepared by fluxing Bermudez asphalt.

Sheet asphalt construction contemplates a mixture of the fluxed asphalt with properly graded sand and a mineral filler. The asphalt and sand should be heated separately to a temperature of from 275° F. to 325° F. The filler should be added to the hot sand and followed by the asphalt. The mixture should contain from 9 per cent to 12 per cent bitumen and will vary within these limits with the exact grading of the aggregate. After thorough mixing the hot mixture should be deposited in a uniform layer on a binder course which has been previously laid over a concrete base. It should be laid to such depth that it will yield a uniform layer 1½ or 2 inches in thickness as may be required after thorough rolling.

NA–8. FLUXED TRINIDAD ASPHALT FOR CONSTRUCTION.

General. The fluxed native asphalt shall be homogeneous, free from water, and shall not foam when heated to 175°C. (347°F.).

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.)______1.200 to 1.250
2. Flash point__________________not less than 175°C. (347°F.)
3. Melting point_____________45°C. (113°F.) to 55°C. (131°F.)
4. Penetration at 25°C. (77°F.), 100 g., 5 sec_________50 to 60
5. Loss at 163°C. (325°F.), 5 hours_______not more than 3.0%
    a. Penetration of residue at 25°C. (77°F.), 100 g., 5 sec___________________________________not less than 25
6. Total bitumen (soluble in carbon disulphide), not less than 68.0%
    b. Inorganic matter insoluble_____________20.0% to 30.0%

Methods of testing. Tests of the physical and chemical properties of the fluxed native asphalt shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Melting point, A. S. T. M. Tentative Standard D 36–16 T. Proc. A. S. T. M. 1916, p. 549.
4. Penetration, A. S. T. M. Standard Test D 5–16.
5. Volatilization test, U. S. Department of Agriculture Bulletin, 314, p. 19, using 50-gram sample.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used for sheet asphalt construction in the northern United States. It is intended to cover satisfactory grades of products prepared by fluxing Trinidad asphalt.

Sheet asphalt construction contemplates a mixture of the fluxed asphalt with properly graded sand and a mineral filler. The asphalt and sand should be heated separately to a temperture of from 275° F. to 325° F. The filler should be added to the hot sand and followed by the asphalt. The mixture should contain from 9 per cent to 12 per cent bitumen and will vary within these limits with the exact grading of the aggregate. After thorough mixing the hot mixture should be deposited in a uniform layer on a binder course which has been previously laid over a concrete base. It should be laid to such depth that it will yield a uniform layer 1½ or 2 inches in thickness as may be required after thorough rolling.

NA-9. FLUXED TRINIDAD ASPHALT FOR CONSTRUCTION.

General. The fluxed native asphalt shall be homogeneous, free from water, and shall not foam when heated to 175° C. (347° F.).

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity, 25°/25° C. (77°/77° F.)____1.210 to 1.270
2. Flash point_______________not less than 175° C. (347° F.)
3. Melting point________50° C. (122° F.) to 60° C. (140° F.)
4. Penetration at 25° C. (77° F.), 100 g., 5 sec_______40 to 50
5. Loss at 163° C. (325° F.), 5 hours____not more than 3.0%
    a. Penetration of residue at 25° C. (77° F.), 100 g., 5 sec______________________________not less than 20
6. Total bitumen (soluble in carbon disulphide), not less than 65.0%
    b. Inorganic matter insoluble___________22.0% to 32.0%

Methods of testing. Tests of the physical and chemical properties of the fluxed native asphalt shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Flash point (open cup), U. S. Department of Agriculture Bulletin 314, p. 17.
3. Melting point, A. S. T. M. Tentative Standard D 36–16 T. Proc. A. S. T. M. 1916, p. 549.
4. Penetration, A. S. T. M. Standard Test D 5–16.
5. Volatilization test, U. S. Department of Agriculture Bulletin 314, p. 19, using 50-gram sample.
6. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used for sheet asphalt construction in the southern United States or for the same type of construction in the northern United States to withstand very heavy traffic. It is intended to cover satisfactory grades of products prepared by fluxing Trinidad asphalt.

Sheet asphalt construction contemplates a mixture of the fluxed asphalt with properly graded sand and a mineral filler. The asphalt and sand should be heated separately to a temperature of from 275° F. to 325° F. The filler should be added to the hot sand and followed by the asphalt. The mixture should contain from 9 per cent to 12 per cent bitumen and will vary within these limits with the exact grading of the aggregate. After thorough mixing the hot mixture should be deposited in a uniform layer on a binder course which has been previously laid over a concrete base. It should be laid to such depth that it will yield a uniform layer 1½ or 2 inches in thickness as may be required after thoroughly rolling.

TC-1. TAR FOR COLD APPLICATION.

General.

The tar shall be homogeneous.

Physical and chemical properties.

It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.)__not less than 1.100
2. Specific viscosity at 40° C. (104° F.)_______________8 to 13
3. Total distillate by weight:
   To 170° C. (338° F.)___________not more than 5 per cent
   To 270° C. (518° F.)__________not more than 30 per cent
   To 300° C. (572° F.)__________not more than 40 per cent
4. Total bitumen (soluble in carbon disulphide),
   not less than 90%

Methods of testing.

Tests of the physical and chemical properties of the tar shall be made in accordance with the following methods:

1. Specific gravity, Department of Agriculture Bulletin 314, p. 4.
2. Specific viscosity (on first 50 c.c.) U. S. Department of Agriculture Bulletin 314, p. 7.
3. Distillation test, A. S. T. M. Standard Test D 20–16.
4. Total bitumen (soluble in carbon disulphide)
   not less than 90%
   314, p. 25.

This specification provides primarily for a material to be used as a primer coat on macadam, gravel, or shell roads to be immediately followed by a more viscous product (Specification TH–1). It may be used alone for the cold surface treatment of the above types of road in the manner described under Specification TC–2, which provides for a material better adapted to this purpose. It may also be used for the maintenance of tar macadam or tar concrete roads. The specification is intended to cover gas house, coke oven, and water gas tar products.

If used as a primer coat, the road surface should be in a good state of repair, well consolidated, free from holes or depressions, and thoroughly swept for the removal of dust and detritus before the application is made. Newly constructed or reconstructed roads should be permitted to consolidate under traffic before the tar is applied. The tar may be applied without heating by a pressure distributer at a uniform rate of 0.2 to 0.3 gallon per square yard. The primer coat should be permitted to soak in undisturbed for from 18 to 24 hours, after which it should be given a very light covering of stons chips or fine gravel in just sufficient quantity to prevent the distributor wheels from picking up the surface. The second application should be a heavier tar (Specification TH–1). Roads having a double treatment as above described should yield somewhat longer service than those having only a single treatment. They may be maintained by subsequent hot or cold applications of tar (Specifications TH–1 or TC–2).

TC-2. TAR FOR COLD APPLICATION.

General. The tar shall be homogeneous.

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.)_____1.100 to 1.140
2. Specific viscosity at 40° C. (104° F.)_____________25 to 35
3. Total distillate by weight:
    To 170° C. (338° F.)_________not more than 2.0 per cent
    To 270° C. (518° F.)________not more than 25.0 per cent
    To 300° C. (572° F.)________not more than 35.0 per cent
4. Total bitumen (soluble in carbon disulphide)__ 95% to100%

Methods of testing. Tests of the physical and chemical properties of the tar shall be made in accordance with the following methods:

1. Specific gravity, Department of Agriculture Bulletin 314, p. 4.
2. Specific viscosity (on first 50 c. c.), U. S. Department of Agriculture Bulletin 314, p. 7.
3. Distillation test, A. S. T. M. Standard Test D 20–16.
4. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides primarily for a material to be used in the surface treatment of macadam, gravel, or shell roads to form a thin wearing mat or carpet which may be built up by subsequent maintenance treatment of either the same type of material or a heavier product (Specification TH–1). It may also be used for maintenance of tar macadam or tar concrete roads, for which purpose it is considered preferable to specification TC–1. The specification is intended to cover water-gas tar and low carbon coke-oven tar products.

A successful treatment requires that the road surface shall be in a good state of repair, well consolidated, free from holes or depressions, and thoroughly swept for the removal of dust and detritus before the application is made. Newly constructed or reconstructed roads should be permitted to consolidate under traffic before the tar is applied. The tar may usually be applied without heating excepting when cold weather renders it too viscous to distribute properly. The initial application should be made by means of a pressure distributor at the rate of from one-third to one-half gallon per square yard. It should be covered with a uniform layer of dustless broken stone all of which will pass a one-half or three-quarter inch laboratory screen or pea gravel, which will pass a one-half inch laboratory screen in an amount just sufficient to absorb the bitumen and to prevent the surface from picking up under traffic. Subsequent applications may be made by a pressure distributor or by brooming the tar uniformly over the road surface. From one-tenth to one-fifth gallon per square yard will usually prove sufficient, and this may be covered with coarse sand or stone chips which will pass a one-half inch laboratory screen. Under favorable conditions a treatment should last throughout at least one season.

TC–3. TAR FOR COLD PATCHING.

General.

The tar shall be homogeneous.

Physical and chemical properties.

It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.)______1.100 to 1.200
2. Specific viscosity at 40° C. (104° F.)______________40 to 70
3. Total distillate by weight:
    To 170° C. (338° F.)___________not less than 2.0 per cent
    To 270° C. (518° F.)___________________15 to 25 per cent
    To 300° C. (572° F.)________not more than 30.0 per cent
4. Total bitumen (soluble in carbon disulphide), not less than 80%

Methods of testing.

Tests of the physical and chemical properties of the tar shall be made in accordance with the following methods:

1. Specific gravity, Department of Agriculture Bulletin 314, p. 4.
2. Specific viscosity (on first 50 c. c.), U. S. Department of Agriculture Bulletin 314, p. 7.
3. Distillation test, A. S. T. M. Standard Test D 20–16.
4. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the repair of surface breaks, holes and depressions in bituminous-bound and surface-treated roads. It is intended to cover preparations consisting of gas-house, coke-oven, or water-gas tars or pitches which have been rendered sufficiently fluid by the addition of distillates to enable them to be handled without heating.

For surface breaks and shallow depressions or those which in general do not exceed one-half inch in depth, a patch may be made by painting the bottom of the depression with the tar, and scattering over it a sufficient amount of stone chips to fill the depression.

In repairing deeper depressions and holes, the old material should be removed to yield a clean bottom. The sides of the hole should be cut approximately vertical. A mixture of graded broken stone with just a sufficient amount of tar to thoroughly coat each particle should be prepared, and firmly tamped into the hole to form a neat patch in the surface. A thin layer of sand or screenings over the patch will prevent it from picking up under traffic.

TH–1. REFINED TAR FOR HOT APPLICATION.

General. The refined tar shall be homogeneous and free from water.

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity 25°/25°C. (77°/77°F.)__not less than 1.130
2. Float test at 32°C. (90°F.)____________ 60 sec. to 150 sec.
3. Total distillate by weight:
   - To 170°C. (338°F.)________ not more than 1 per cent
   - To 270°C. (518°F.)_________ not more than 15 per cent
   - To 300°C. (572°F.)_________ not more than 25 per cent
4. Total bitumen (soluble in carbon disulphide), not less than 85 per cent

Methods of testing. Tests of the physical and chemical properties of the refined tar shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Float test, U. S. Department of Agriculture Bulletin 314, p. 9.
3. Distillation test, A. S. T. M. Standard Test D 20–16.
4. Total bitumen, U. S. Department of Agriculture Bulletin 314, p 25.

This specification provides primarily for a material to be used in the surface treatment of macadam, gravel, or shell roads, either with or without a primer coat (Specification TC–1) to form a wearing mat or carpet. A primer coat is particularly desirable on gravel or shell roads. It may also be used for the maintenance of tar macadam or tar concrete roads. The specification is intended to cover gas-house, coke-oven, and water-gas tar products.

A successful treatment requires that the road surface shall be in a good state of repair, well consolidated, free from holes or depressions, and thoroughly swept for the removal of dust and detritus before the application is made, if a primer coat has not already been applied. Newly constructed and reconstructed roads should be permitted to consolidate under traffic before the tar is applied. The tar should be heated to a temperature of 200° F. to 250° F. before applying, and the application should be made by means of a pressure distributor at the rate of from one-third to one-half gallon per square yard. It should be covered with a uniform layer of dustless broken stone all of which will pass a 1-inch or three-quarter-inch laboratory screen or pea gravel which will pass a one-half-inch laboratory screen in an amount just sufficient to absorb the bitumen and to prevent the surface from picking up under traffic. Subsequent application may be made by a pressure distributor or by brooming the tar uniformly over the road surface. From one-tenth to one-fifth gallon per square yard will usually prove sufficient, and this may be covered with coarse sand or stone chips which will pass a half-inch laboratory screen. Under favorable conditions with occasional patching of any breaks in the surface a treatment should last for several years.

TP-1. REFINED TAR FOR CONSTRUCTION.

General. The refined tar shall be homogeneous and free from water.

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.)------1.150 to 1.200
2. Float test at 50° C. (122° F.)------------90 sec. to 120 sec.
3. Total distillate by weight:
   To 170° C. (336° F.)----------not more than 1.0 per cent
   To 270° C. (518° F.)---------not more than 10.0 per cent
   To 300° C. (572° F.)---------not more than 20.0 per cent
   (*a*) Melting point of residue,
   not more than 65° C. (149° F.)
4. Total bitumen (soluble in carbon disulphide)--97% to 100%

Methods of testing. Tests of the physical and chemical properties of the refined tar shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Float test, U. S. Department of Agriculture Bulletin 314, p. 9.
3. Distillation test, A. S. T. M. Standard Test D 20–16.
   (*a*) Melting point, A. S. T. M. Tentative Standard D 36–16 T, Proc. A. S. T. M. 1916—p. 549.
4. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of bituminous macadam in the extreme northern United States. It is intended to cover refined water-gas tar products.

It should be applied at a temperature of from 250° F. to 300° F. to the upper or wearing course of compacted broken stone at the rate of from 1½ to 1¾ gallons per square yard. The application may be made by means of pouring pots or by a pressure distributor so designed that it will not produce ruts during application. The above quantities are based on a wearing course 3 inches in thickness before rolling, composed of a product which will pass a 2 to 3 inch laboratory screen and be retained on a 1-inch laboratory screen. The exact range in size should be governed by the kind and quality of rock used. The application should be followed by a sufficient amount of clean small-sized broken stone to fill the surface voids when thoroughly rolled. A seal coat of the same tar or of hot asphalt (Specification OA–6) should then be applied at the rate of 0.4 to 0.6 gallon per square yard and covered with a sufficient amount of stone chips to just absorb the excess bitumen. Roads of this character may be maintained with tar surface treatments, using the materials and methods given under Specifications TC–1, TC–2, or TH–1. Such maintenance treatments should be applied whenever the wear comes directly upon the wearing course rock.

TP–2. REFINED TAR FOR CONSTRUCTION.

General. The refined tar shall be homogeneous and free from water.

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity 25° C./25° C. (77°/77° F.)	1.200 to 1.250
2. Float test at 50° C. (122° F.)	90 sec. to 120 sec.
3. Total distillate by weight:	
To 170° C. (338° F.)	not more than 1.0 per cent
To 270° C. (518° F.)	not more than 10.0 per cent
To 300° C. (572° F.)	not more than 20.0 per cent
a. Melting point of residue	not more than 65° C. (149° F.)
4. Total bitumen (soluble in carbon disulphide),	80 per cent to 97 per cent

Methods of testing. Tests of the physical and chemical properties of the refined tar shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Float test, U. S. Department of Agriculture Bulletin 314, p. 9.
3. Distillation test, A. S. T. M. Standard Test D 20–16.
    a. Melting point A. S. T. M. Tentative Standard D 36–16 T, Proc A. S. T. M., 1916, 549.
4 Total bitumen, U S Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of bituminous macadam in the extreme northern United States. It is intended to cover refined gas-house or coke-oven tar.

It should be applied at a temperature of from 250° F. to 300° F. to the upper or wearing course of compacted broken stone at the rate of from 1½ to 1¾ gallons per square yard. The application may be made by means of pouring pots or by a pressure distributor so designed that it will not produce ruts during application. The above quantities are based on a wearing course 3 inches in thickness before rolling, composed of a product which will pass a 2 to 3 inch laboratory screen and be retained on a 1-inch laboratory screen. The exact range in size should be governed by the kind and quality of rock used. The application should be followed by a sufficient amount of clean small sized broken stone to fill the surface voids when thoroughly rolled. A seal coat of the same tar or of hot asphalt (Specification OA–6) should then be applied at the rate of 0.4 to 0.6 gallon per square yard and covered with a sufficient amount of stone chips to just absorb the excess bitumen. Roads of this character may be maintained with tar surface treatments, using the materials and methods given under specifications TC–1, TC–2, or TH–1. Such maintenance treatments should be applied whenever the wear comes directly upon the wearing course rock.

TP-3. REFINED TAR FOR CONSTRUCTION.

General.

The refined tar shall be homogeneous and free from water.

Physical and chemical properties.

It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.)______1.150 to 1.200
2. Float test at 50° C. (122° F.)___________120 sec. to 150 sec.
3. Total distillate by weight:
   - To 170° C. (338° F.)________not more than 1.0 per cent
   - To 270° C. (518° F.)________not more than 10.0 per cent
   - To 300° C. (572° F.)________not more than 20.0 per cent
     - *a.* Melting point of residue, not more than 65° C. (149° F.)
4. Total bitumen (soluble in carbon disulphide)__97% to 100%

Methods of testing.

Tests of the physical and chemical properties of the refined tar shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Float test, U. S. Department of Agriculture Bulletin 314, p. 9.
3. Distillation test, A. S. T. M. Standard Test D 20–16.
   - *a.* Melting point, A. S. T. M. Tentative Standard D 36–16 T. Proc. A. S. T. M. 1916, p. 549.
4. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of bituminous macadam or one-size-stone bituminous concrete in the northern United States. It is intended to cover refined water-gas tar products.

In bituminous macadam construction it should be applied in the manner outlined under Specification TP–2.

One-size-stone bituminous concrete contemplates a mixture of the tar with a crusher product passing a 1¼ inch screen and retained upon a ½ inch screen. The tar should be heated to a temperature of from 225° F., to 275° F., and the crushed stone to a temperature of from 150° F., to 250° F., before mixing. The mixture should contain from 5 per cent to 7 per cent bitumen and will vary within these limits with the character of the rock and the exact grading of the aggregate. The hot mixture should be deposited in a uniform layer over a concrete or well compacted broken stone or gravel foundation to such depth that it will yield a uniform layer two inches in thickness after thorough rolling. A seal coat of the same tar or of hot asphalt (Specification OA–6) should then be applied at the rate of 0.4 to 0.6 gallon per square yard and covered with a sufficient amount of stone chips to just absorb the excess bitumen. Roads of this character may be maintained with tar surface treatments using the materials and methods given under Specifications TC–1, TC–2, or TH–1. Such maintenance treatments should be applied whenever the wear comes directly upon the wearing course rock.

TP-4. REFINED TAR FOR CONSTRUCTION.

General. The refined tar shall be homogeneous and free from water.

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.)------1.200 to 1.250
2. Float test at 50° C. (122° F.)----------120 sec. to 150 sec.
3. Total distillate by weight:
   - To 170° C. (338° F.)--------not more than 1.0 per cent
   - To 270° C. (518° F.)--------not more than 10.0 per cent
   - To 300° C. (572° F.)--------not more than 20.0 per cent
   - *a.* Melting point of residue-not more than 65° C. (149° F.)
4. Total bitumen (soluble in carbon disulphide)--80% to 97%

Methods of testing. Tests of the physical and chemical properties of the refined tar shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Float test, U. S. Department of Agriculture Bulletin 314, p. 9.
3. Distillation tests, A. S. T. M. Standard Test D20–16.
   - *a.* Melting point, A. S. T. M. Tentative Standard D36–16 T, Proc. A. S. T. M. 1916, p. 549.
4. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of bituminous macadam or one size stone bituminous concrete in the northern United States. It is intended to cover refined gas-house or coke-oven tar.

In bituminous macadam construction it should be applied in the manner outlined under Specification TP–2.

One-size stone bituminous concrete contemplates a mixture of the tar with a crusher product passing a 1¼-inch screen and retained upon a one-half-inch screen. The tar should be heated to a temperature of from 225° F. to 275° F. and the crushed stone to a temperature of from 150° F. to 250° F. before mixing. The mixture should contain from 5 per cent to 7 per cent bitumen, and will vary within these limits with the character of the rock and the exact grading of the aggregate. The hot mixture should be deposited in a uniform layer over a concrete or well compacted broken stone or gravel foundation to such depth that it will yield a uniform layer 2 inches in thickness after thorough rolling. A seal coat of the same tar or of hot asphalt (Specification OA–6) should then be applied at the rate of 0.4 to 0.6 gallon per square yard and covered with a sufficient amount of stone chips to just absorb the excess bitumen. Roads of this character may be maintained with tar surface treatments, using the materials and methods given under Specifications TC–1, TC–2, or TH–1. Such maintenance treatments should be applied whenever the wear comes directly upon the wearing-course rock.

TP-5. REFINED TAR FOR CONSTRUCTION.

General. The refined tar shall be homogeneous and free from water.

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity, 25°/25° C. (77°/77° F.) ------ 1.150 to 1.200
2. Float test at 50° C (122° F.) ---------- 150 sec. to 180 sec.
3. Total distillate by weight:
   - To 170° C. (338° F.) ---------- not more than 1.0 per cent
   - To 270° C. (518° F.) ---------- not more than 10.0 per cent
   - To 300° C. (572° F.) ---------- not more than 20.0 per cent
     - *a.* Melting point of residue, not more than 65° C. (149° F.)
4. Total bitumen (soluble in carbon disulphide) -- 97% to 100%

Methods of testing. Tests of the physical and chemical properties of the refined tar shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Float test, U. S. Department of Agriculture Bulletin 314, p. 9.
3. Distillation test, A. S. T. M. Standard Test D 20–16.
   - *a.* Melting point, A. S. T. M. Tentative Standard D 36–10 T, Proc. A. S. T. M. 1916, p. 549.
4. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of bituminous macadam or one size stone bituminous concrete in the southern United States. It is intended to cover refined water-gas tar products.

In bituminous macadam construction it should be applied in the manner outlined under Specification TP–2.

In one size stone bituminous-concrete construction it should be used in the manner outlined under Specification TP–4.

In either type of construction the tar should be heated to from 250° F. to 300° F. Roads of this character may be maintained with tar surface treatments, using the materials and methods given under Specifications TC–1, TC–2, or TH–1. Such maintenance treatments should be applied whenever the wear comes directly upon the wearing-course rock.

TP–6. REFINED TAR FOR CONSTRUCTION.

General. The refined tar shall be homogeneous and free from water.

Physical and chemical properties. It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.) ...... 1.200 to 1.250
2. Float test at 50° C. (122° F.) .... 150 sec. to 180 sec.
3. Total distillate by weight:
    - To 170° C. (338° F.) .... not more than 1.0 per cent
    - To 270° C. (518° F.) .... not more than 10.0 per cent
    - To 300° C. (572° F.) .... not more than 20.0 per cent
        - *a.* Melting point of residue, not more than 65° C. (149° F.)
4. Total bitumen (soluble in carbon disulphide) .. 80% to 97%

Methods of testing. Tests of the physical and chemical properties of the refined tar shall be made in accordance with the following methods:

1. Specific gravity, U. S. Department of Agriculture Bulletin 314, p. 5.
2. Float test, U. S. Department of Agriculture Bulletin 314, p. 9.
3. Distillation test, A. S. T. M. Standard Test D 20–16.
    - *a.* Melting point, A. S. T. M. Tentative Standard D 36–16 T, Proc. A. S. T. M. 1916, p. 549.
4. Total bitumen, U. S. Department of Agriculture Bulletin 314, p. 25.

This specification provides for a material to be used in the construction of bituminous macadam or one-size stone bituminous concrete in the southern United States. It is intended to cover refined gas-house or coke-oven tar.

In bituminous-macadam construction it should be applied in the manner outlined under Specification TP–2.

In one size stone bituminous-concrete construction it should be used in the manner outlined under Specification TP–4.

In either type of construction the tar should be heated to from 250° F. to 300° F. Roads of this character may be maintained with tar surface treatments, using the materials and methods given under Specifications TC–1, TC–2, or TH–1. Such maintenance treatments should be applied whenever the wear comes directly upon the wearing-course rock.

METHODS OF TESTING.

The following methods of testing are those to which reference is made in the foregoing specifications. The descriptions taken from Department of Agriculture Bulletin 314 have been condensed, but not changed in any essential particular unless so indicated in the specifications proper.

SPECIFIC GRAVITY.

[Bulletin 314, p. 4.]

HYDROMETER METHOD.

A sufficient quantity of material is poured into a tin cup, which is then placed in a large dish containing cold or warm water as occasion may require. The material in the cup should be stirred with a thermometer until it is brought to a temperature of 25° C., after which it should be immediately poured into a hydrometer jar and its gravity determined by means of the proper hydrometer. In case the hydrometer sinks slowly, owing to the viscosity of the material, it should be given sufficient time to come to a definite resting point, and this point should be checked by raising the hydrometer and allowing it to sink a second time. The hydrometer should never be pushed below the point at which it naturally comes to rest until the last reading has been made. It may then be pushed below the reading for a distance of three or four of the small divisions on the scale, whereupon it should immediately begin to rise. If it fails to do so, the material is too viscous for the hydrometer method, and the pycnometer method should be employed.

The direct specific gravity reading obtained by the foregoing method is based upon water at 15.5° C. taken as unity. For all practical purposes this reading may be corrected to water at 25° C., considered as unity, by multiplying it by 1.002. Thus:

Specific gravity 25° C./25° C.=specific gravity 25° C./15.5° C.×1.002.

SPECIFIC GRAVITY.

[Bulletin 314, p. 5.]

PYCNOMETER METHOD.

The pycnometer, shown in figure 1, consists of a fairly heavy, straight-walled glass tube, 70 millimeters long and 22 millimeters in diameter, carefully ground to receive an accurately fitting solid glass stopper with a hole of 1.6 millimeters bore in place of the usual capillary opening. The lower part of this stopper is made concave in order to allow all air bubbles to escape through the bore. The depth of the cup-shaped depression is 4.8 millimeters at the center. The stoppered tube has a capacity of about 24 cubic centimeters and when empty weighs about 28 grams.

The clean, dry pycnometer is first weighed empty and this weight is called "a". It is then filled in the usual manner with freshly distilled water at 25° C., and the weight is again taken and called "b". A small amount of the bitumen should be placed in a spoon and brought to a fluid condition by the gentle application of heat, with care that no loss by evaporation occurs. When sufficiently fluid, enough is poured into the dry pycnometer, which may also be warmed, to fill it about half full, without allowing the material to touch the sides of the tube above the desired level. The tube and contents are then allowed to cool to room temperature, after which the tube is carefully weighed with the stopper. This weight is called "c". Distilled water, at 25° C., is then poured in until the pycnometer is full. After this the stopper is inserted, and the whole cooled to 25° C. by a 30-minute immersion in a beaker of distilled water maintained at this temperature. All surplus moisture is then removed with a soft cloth, and the pycnometer and contents are weighed. This weight is called "d". From the weights obtained the specific gravity of the bitumen may be readily calculated by the following formula:

$$\text{Specific gravity } 25^\circ \text{ C.}/25^\circ \text{ C.} = \frac{c-a}{(b-a)-(d-c)}$$

The specific gravity of fluid bitumen may be determined in the ordinary manner with this pycnometer by completely filling it with the material and dividing the weight of the bitumen thus obtained by that of the same volume of water.

FIG. 1.—Pycnometer (Hubbard type).

FLASH POINT.

[Bulletin 314, p. 17.]

OPEN-CUP METHOD.

The open-cup oil tester, shown in figure 2, consists of a brass oil cup *a* of about 100 cubic centimeters capacity, and an outer vessel *b* which serves as an air jacket; a suitable thermometer *c* is suspended from the wire support *d* directly over the center of the cup so that its bulb is entirely covered with oil but does not touch the bottom of the cup. The testing flame is obtained from a jet of gas passed through a piece of glass tubing, and should be about 5 millimeters in length.

The test is made by first filling the oil cup with the material under examination to within about 5 millimeters of the top. The Bunsen flame is then applied in such a manner that the temperature of the material in the cup is raised at the rate of 5° C. per minute. From time to time the testing flame is brought almost in contact with the surface of the oil. A distinct flicker or flash over the entire surface of the oil shows that the flash point is reached and the temperature at this point is taken.

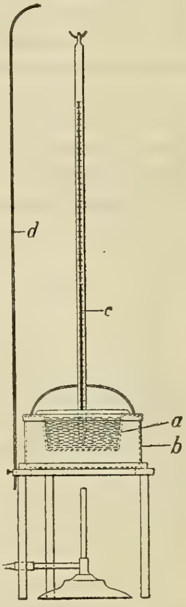

FIG. 2.—Open-cup oil tester.

SPECIFIC VISCOSITY.

[Bulletin 314, p. 7.]

ENGLER VISCOSIMETER METHOD.

The specific viscosity of fluid bituminous road materials is determined at the specified temperature by means of the Engler viscosimeter. This apparatus shown in figure 3 may be described as follows: *a* is a brass vessel for holding the material to be tested, and may be closed by the cover *b*. To the conical bottom of *a* is fitted a conical outflow tube *c*, exactly 20 millimeters long, with a diameter at the top of 2.9 millimeters and at the bottom of 2.8 millimeters. This tube may be closed and opened by the pointed hardwood stopper *d*. Pointed metal projections are placed on the inside of *a* at equal distances from the bottom and serve for measuring the charge of material, which is 240 cubic centimeters. The thermometer *e* is used to ascertain the temperature of the material to be tested. The vessel *a* is surrounded by a brass jacket *f*, which holds the material used as a heating bath, either water or cottonseed oil, according to the temperature at which the test is to be made. A tripod *g* serves as a support for the apparatus and also carries a ring burner *h* by means of which the bath is directly heated. The measuring cylinder of 100 cubic centimeters capacity, which is sufficiently accurate for work with road materials, is placed directly under the outflow tube.

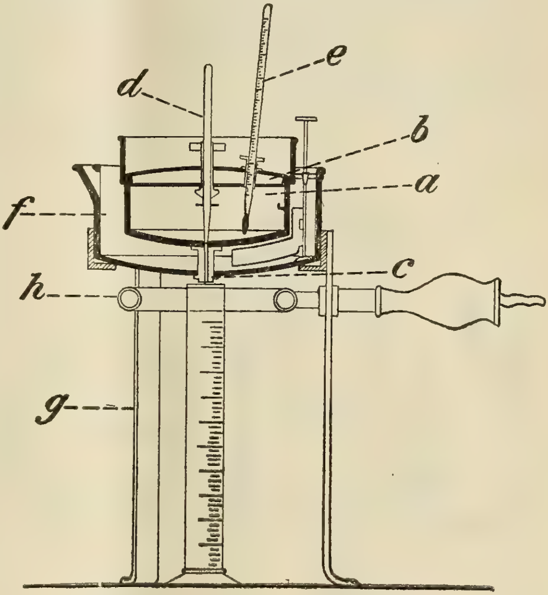

FIG. 3.—Engler viscosimeter.

As all viscosity determinations should be compared with that of water at 25° C., the apparatus should be previously calibrated as follows: The cup and outlet tube should first be scrupulously cleaned. A piece of soft tissue paper is convenient for cleaning the latter. The stopper is then inserted in the tube and the cup filled with water at 25° C. to the top of the projections. The measuring cylinder should be placed directly under the outflow tube so that the material, upon flowing out, will not touch the sides, and the stopper may then be removed. The time required for 50 cubic centimeters to run out should be ascertained by means of a stop watch and the results so obtained should be checked a number of times. The time should be about 11 seconds.

Bituminous road materials are tested in the same manner as water and the temperature at which the test is made is controlled by the bath. The material should be brought to the desired temperature and maintained there for at least three minutes before making the test. The results are expressed as specific viscosity compared with water at 25° C., as follows:

$$\text{Specific viscosity at a}^\circ\text{ C.} = \frac{\text{seconds for passage of given volume at a}^\circ\text{ C.}}{\text{seconds for passage of same volume of water at }25^\circ\text{ C.}}$$

VOLATILIZATION TEST.

[Bulletin 314, p. 19.]

The oven shown in figure 4, known as the New York testing laboratory oven, is used by the office of public roads and rural engineering, although any other form may be used that will give a uniform temperature throughout all parts where samples are placed. The bulb of one of the termometers is immersed in a sample of some fluid, nonvolatile bitumen, while the other is kept in air at the same level. The first thermometer serves to show the temperature of the samples during the test, while the latter gives prompt warning of any sudden changes in temperature due to irregularities in the gas pressure, etc.

Before making the test the interior of the oven should show a temperature of 163° C. as registered by the thermometer in air. A round tin box[1] 6 centimeters in diameter and 2 centimeters deep is accurately weighed after carefully wiping with a towel to remove any grease or dirt. About 20 grams of the material to be tested is then placed in the box. The material may then be weighed on a rough balance, if one is at hand, after which the accurate weight, which should not vary more than 0.2 gram from the specified amount is obtained. It may be necessary to warm some of the material in order to handle it conveniently, after which it must be allowed to cool before determining the accurate weight.

The sample should now be placed in the oven, where it is allowed to remain for a period of five hours, during which time the temperature as shown by the thermometer in bitumen should not vary at any time more than 2° C. from 163° C. The sample is then removed from the oven, allowed to cool, and reweighed. From the difference between this weight and the total weight before heating, the percentage of loss on the amount of material taken is calculated.

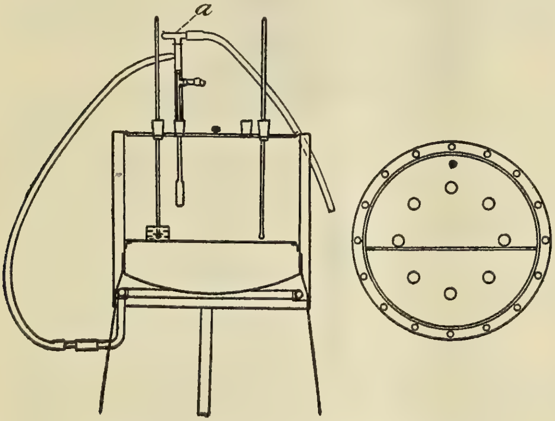

FIG. 4.—New York Testing Laboratory oven.

Highly volatile and nonvolatile materials should not be subjected to this test at the same time in the same oven, owing to a tendency on the part of the latter to absorb some of the volatile products of the former.

Some relative idea of the amount of hardening which has taken place may be obtained from the results of a float or penetration test made on the residue, as compared with the results of the same tests on the original sample. Before any tests are made on the residue, it should be melted and thoroughly stirred while cooling.

FLOAT TEST.

[Bulletin 314, p. 9.]

NEW YORK TESTING LABORATORY FLOAT APPARATUS.

The float apparatus consists of two parts, an aluminum float or saucer and a conical brass collar (fig. 5). The two parts are made separately, so that one float may be used with a number of brass collars.

In making the test the brass collar *b* is placed with the small end down on a brass plate, which has been previously amalgamated with mercury by first rubbing it with a dilute solution of mercuric chloride or nitrate and then with mercury. A small quantity of the material to be tested is heated in a metal spoon until quite fluid, with care that it suffers no appreciable loss by volatilization and that it is kept free from air bubbles. It is then poured into the collar in a thin stream until slightly more than level with the top. The surplus may be removed, after the material has cooled to room temperature, by means of a spatula or steel knife, which has been slightly heated. The collar and plate are then placed in a tin cup containing ice water maintained at 5° C., and left in this bath for at least 15 minutes. Meanwhile another cup of 1 quart capacity is filled about three-fourths full of water and placed on a tripod, and the water is heated to the specified temperture at which the test is to be made. This temperature should be accurately maintained, and should at no time throughout the entire test be allowed to vary more than one-half a degree centigrade from the temperature specified. After the material to be tested has been kept in the ice water for at least 15 minutes, the collar with its contents is removed from the plate and screwed into the aluminum float *a*, which is then immediately floated in the warmed bath. As the plug of bituminous material becomes warm and fluid, it is gradually forced upward and out of the collar, until water gains entrance to the saucer and causes it to sink.

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[1] The box for a 50-gram sample should be 5½ centimeters in diameter and 3½ centimeters deep.

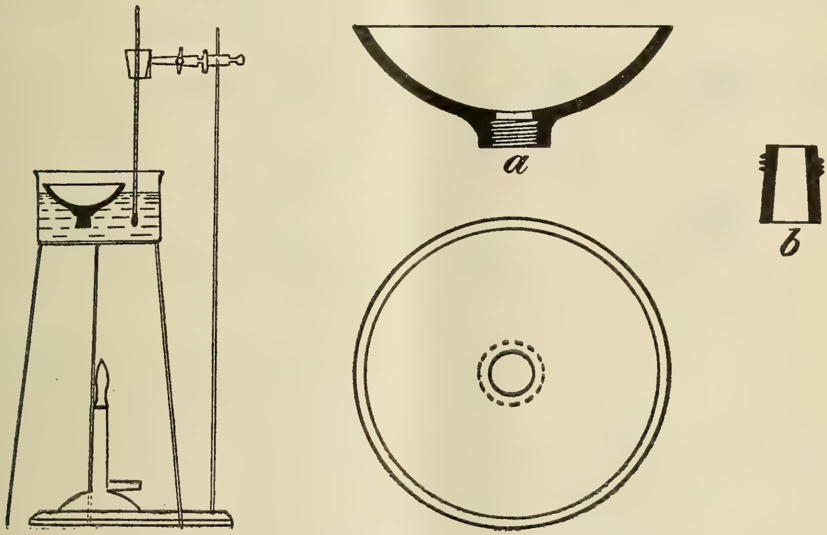

FIG. 5.—New York Testing Laboratory float apparatus.

The time in seconds between placing the apparatus on the water and when the water breaks through the bitumen is determined by means of a stop watch, and is taken as a measure of the consistency of the material under examination.

TOTAL BITUMEN.

[Bulletin 314, p. 25.]

GOOCH CRUCIBLE METHOD.

This test consists in dissolving the bitumen in carbon disulphide and recovering any insoluble matter by filtering the solution through an asbestos felt. The form of Gooch crucible best adapted for the determination is 4.4 centimeters wide at the top, tapering to 3.6 centimeters at the bottom, and is 2.5 centimeters deep.

For preparing the felt the necessary appartatus is arranged as shown in figure 6, in which *a* is the filtering flask, *b* a rubber stopper, *c* the filter tube, and *d* a section of rubber tubing which tightly clasps the Gooch crucible *e*. The asbestos is cut with scissors into pieces not exceeding 1 centimeter in length, after which it is shaken up with just sufficient water to pour easily. The crucible is filled with the suspended asbestos, which is allowed to settle for a few moments. A light suction is then applied to draw off all the water and leave a firm mat of asbestos in the crucible. More of the suspended material is added, and the operation is repeated until the felt is so dense that it scarcely transmits light when held so that the bottom of the crucible is between the eye and the source of light. The felt should then be washed several times with water and drawn firmly against the bottom of the crucible by an increased suction. The crucible is removed to a drying oven for a few minutes, after which it is ignited at red heat over a Bunsen burner, cooled in a desiccator, and weighed.

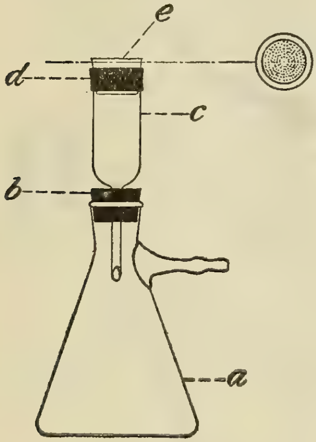

FIG. 6.—Apparatus for determining soluble bitumen.

From 1 to 2 grams of the bituminous material is now placed in the Erlenmeyer flask, which has been previously weighed, and the accurate weight of the sample is obtained. One hundred cubic centimeters of chemically pure carbon disulphide is poured into the flask in small portions, with continual agitation, until all lumps disappear and nothing adheres to the bottom. The flask is then corked and set aside for 15 minutes.

After being weighed, the Gooch crucible containing the felt is set up over the dry pressure flask, as shown in the figure, and the solution of bitumen in carbon disulphide is decanted through the felt without suction by gradually tilting the flask, with care not to stir up any precipitate that may have settled out. At the first sign of any sediment coming out, the decantation is stopped and the filter allowed to drain. A small amount of carbon disulphide is then washed down the sides of the flask, after which the precipitate is brought upon the felt and the flask scrubbed, if necessary, with a feather or "policeman," to remove all adhering material. The contents of the crucible are washed with carbon disulphide, until the washings run colorless. Suction is then applied until there is practically no odor of carbon disulphide in the crucible, after which the outside of the crucible is cleaned with a cloth moistened with a small amount of the solvent. The crucible and contents are dried in a hot-air oven at 100° C. for about 20 minutes, cooled in a desiccator, and weighed. If any appreciable amount of insoluble matter adheres to the flask, it should also be dried and weighed, and any increase over the original weight of the flask should be added to the weight of insoluble matter in the crucible. The total weight of insoluble material may include both organic and mineral matter. The former, if present, is burned off by ignition at a red heat until no incandescent particles remain, thus leaving the mineral matter or ash, which can be weighed on cooling. The difference between the total weight of material insoluble in carbon disulphide and the weight of substance taken equals the total bitumen, and the percentage weights are calculated and reported as total bitumen, and organic and inorganic matter insoluble, on the basis of the weight of material taken for analysis.

This method is quite satisfactory for straight oil and tar products, but where certain natural asphalts are present it will be found practically impossible to retain all of the finely divided mineral matter on an asbestos felt. It is, therefore, generally more accurate to obtain the result for total mineral matter by direct ignition of a 1-gram sample in a platinum crucible. The total bitumen is then determined by deducting from 100 per cent the sum of the percentages of total mineral matter and organic matter insoluble. If the presence of a carbonate mineral is suspected, the percentage of mineral matter may be most accurately obtained by treating the ash from the fixed carbon determination with a few drops of ammonium carbonate solution, drying at 100° C., then heating for a few minutes at a dull red heat, cooling, and weighing again.

When difficulty in filtering is experienced—for instance, when Trinidad asphalt is present in any amount—a period of longer subsidence than 15 minutes is necessary, and the following method proposed by the Committee on Standard Tests for Road Materials of the American Society of Testing Materials is recommended:[1]

From 2 to 15 grams (depending on the richness in bitumen of the substance) is weighed into a 150-cubic centimeter Erlenmyer flask, the tare of which has been previously assertained, and treated with 100 cubic centimeters of carbon disulphide. The flask is then loosely corked and shaken from time to time until practically all large particles of the material have been broken up, when it is set aside and not disturbed for 48 hours. The solution is then decanted off into a similar flask that has been previously weighed, as much of the solvent being poured off as possible without disturbing the residue. The first flask is again treated with fresh carbon disulphide and shaken as before, when it is put away with the second flask and not disturbed for 48 hours.

At the end of this time the contents of the two flasks are carefully decanted off upon a weighed Gooch crucible fitted with an asbestos filter, the contents of the second flask being passed through the filter first. The asbestos filter shall be made of ignited long-fiber amphibole, packed in the bottom of a Gooch crusible to the depth of not over one-eighth of an inch. After passing the contents of both flasks through the filter, the two residues are shaken with more fresh carbon disulphide and set aside for 24 hours without disturbing, or until it is seen that a good subsidation has taken place, when the solvent is again decanted off upon the filter. This washing is continued until the filtrate or washings are practically colorless.

The crucible and both flasks are then dried at 125° C. and weighed. The filtrate containing the bitumen is evaporated, the bituminous residue burned, and the weight of the ash thus obtained added to that of the residue in the two flasks and the crucible. The sum of these weights deducted from the weight of substance taken gives the weight of bitumen extracted.

BITUMEN INSOLUBLE IN NAPHTHA.

[Bulletin 314, p. 28.]

GOOCH CRUCIBLE METHOD.

This determination is made in the same general manner as the total bitumen determination, except that 100 cubic centimeters of 86° to 88° B. paraffin naphtha, at least 85 per cent distilling between 35° C. and 65° C., is employed as a solvent instead of carbon disulphide. Considerable difficulty is sometimes experienced in breaking up some of the heavy semisolid bitumens; the surface of the material is attacked, but it is necessary to remove some of the insoluble matter in order to expose fresh material to the action of the solvent. It is, therefore, advisable to heat the sample after it is weighed, allowing it to cool in a thin layer around the lower part of the flask. If difficulty is still experienced in dissolving the material, a rounded glass rod will be found convenient for breaking up the undissolved particles. Not more than one-half of the total amount of naphtha required should be used until the sample is entirely broken up. The balance of the 100 cubic centimeters is then added, and the flask is twirled a moment in order to mix the contents thoroughly, after which it is corked and set aside for 30 minutes.

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[1] Proc. Am. Soc. for Testing Materials, 1909, Vol. IX, p. 221.

In making the filtration the utmost care should be exercised to avoid stirring up any of the precipitate, in order that the filter may not be clogged and that the first decantation may be as complete as possible. The sides of the flask should then be quickly washed down with naphtha and, when the crucible has drained, the bulk of insoluble matter is brought upon the felt. Suction may be applied when the filtration by gravity almost ceases, but should be used sparingly, as it tends to clog the filter by packing the precipitate too tightly. The material on the felt should never be allowed to run entirely dry until the washing is completed, as shown by the colorless filtrate. When considerable insoluble matter adheres to the flask no attempt should be made to remove it completely. In such cases the adhering material is merely washed until free from soluble matter, and the flask is dried with the crucible at 100° C. for about one hour, after which it is cooled and weighed. The percentage of bitumen insoluble is reported upon the basis of total bitumen taken as 100.

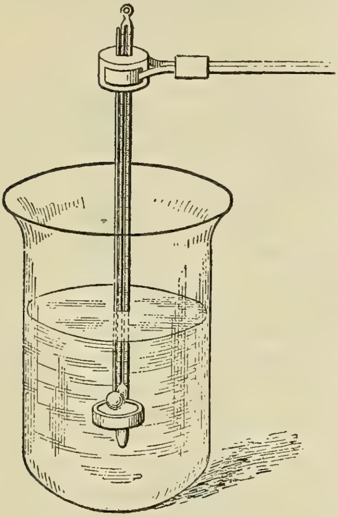

FIG. 7.

The difference between the material insoluble in carbon disulphide and in the naphtha is the bitumen insoluble in the latter. Thus, if in a certain instance it is found that the material insoluble in carbon disulphide amounts to 1 per cent and that 10.9 per cent is insoluble in naphtha, the percentage of bitumen insoluble would be calculated as follows:

$$\frac{\text{Bitumen insoluble in naphtha}}{\text{Total bitumen}}=\frac{10.9-1}{100-1}=\frac{9.9}{99}=10 \text{ per cent}$$

MELTING POINT.

[A. S. T. M. Tentative Standard D36–16T.]

1. The ring and ball method shall be used. (Fig. 7.)

2. The apparatus shall consist of a brass ring 15.875 mm. (five-eighths inch) in diameter, 6.35 mm. (one-fourth inch) deep, 2.38125 (three thirty-seconds inch) wall, suspended 25.40 mm. (one inch) above bottom of beaker; a steel ball 9.525 mm. (three-eighths inch) in diameter, weighing between 3.45 and 3.50 g.; a standardized thermometer; a glass beaker, approximately 600 cc. capacity.

3. Carefully melt the sample and fill the ring with the material to be tested. Remove any excess. Place the ball in the center of the ring and suspend in the

beaker containing approximately 400 cc. of water at a temperature of 5° C. (41° F.). Arrange the thermometer bulb within ½ inch of the sample and at the same level. Apply heat *uniformly* over bottom of the beaker in quantity sufficient to raise the temperature 5° C. (9° F.) per minute. Record the temperature at starting the test and every minute thereafter until the test is completed. The rate of heating is very important. The softening point is the temperature at which the specimen has dropped 1 inch. Successive tests should average within 3° C. For temperatures above 90° C., glycerin shall be used instead of water.

PENETRATION.

[A. S. T. M. Standard Test D5–16.]

I. DEFINITION.

1. *Penetration.*—Penetration is defined as the consistency of a bituminous material expressed as the distance that a standard needle vertically penetrates a sample of the material under known conditions of loading, time and temperature. Where the conditions of test are not specifically mentioned, the load, time and temperature are understood to be 100 g., 5 seconds, 25° C. (77° F.), respectively, and the units of penetration to indicate hundredths of a centimeter.

II. APPARATUS.

2. *Container.*—The container for holding the material to be tested shall be a flat-bottom, cylindrical dish, 55 mm. (2 3/16 inches) in diameter and 35 mm. (1⅜ inches) deep.[1]

3. *Needle.*—The needle[2] for this test shall be of cylindrical steel rod 50.8 mm. (2 inches) long and having a diameter of 1.016 mm. (0.04 inches) and turned on one end to a sharp point having a taper of 6.35 mm. (¼ inch).

4. *Water bath.*—The water bath shall be maintained at a temperature not varying more than 0.1° C. from 25° C. (77° F.). The volume of water shall be not less than 10 liters and the sample shall be immersed to a depth of not less than 10 cm. (4 inches) and shall be supported on a perforated shelf not less than 5 cm. (2 inches) from the bottom of the bath.

5. *Apparatus for penetration.*—Any apparatus which will allow the needle to penetrate without appreciable friction, and which is accurately calibrated to yield results in accordance with the definition of penetration, will be acceptable.

6. *Transfer dish for container.*—The transfer dish for container shall be a small dish or tray of such capacity as will insure complete immersion of the container during the test. It shall be provided with some means which will insure a firm bearing and prevent rocking the container.

III. PREPARATION OF SAMPLE.

7. *Preparation of sample.*—The sample shall be completely melted at the lowest possible temperature and stirred thoroughly until it is homogeneous and free from air bubbles. It shall then be poured into the sample container to a depth of not less than 15 mm. (⅝ inch). The sample shall be protected from dust and allowed to cool in an atmosphere not lower than 18° C. (65° F.) for one hour. It shall then be placed in the water bath along with the transfer dish and allowed to remain one hour.

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[1] This requirement is fulfilled by the American Can Co.'s gill style ointment box, deep pattern, 3-ounce capacity.

[2] Journal of Agricultural Research, Vol. V, No. 24, pp. 1125–1126.

IV. TESTING.

8. *Testing.*—(*a*) In making the test the sample shall be placed in the transfer dish filled with water from the water bath of sufficient depth to completely cover the container. The transfer dish containing the sample shall then be placed upon the stand of the penetration machine. The needle, loaded with specified weight, shall be adjusted to make contact with the surface of the sample. This may be accomplished by making contact of the actual needle point with its image reflected by the surface of the sample from a properly placed source of light. Either the reading of the dial shall then be noted or the needle brought to zero. The needle is then released for the specified period of time, after which the penetration machine is adjusted to measure the distance penetrated.

At least three tests shall be made at points on the surface of the sample not less than 1 cm. (⅜ inch) from the side of the container and not less than 1 cm. (⅜ inch) part. After each test the sample and transfer dish shall be returned to the water bath and the needle shall be carefully wiped toward its point with a clean, dry cloth to remove all adhering bitumen. The reported penetration shall be the average of at least three tests whose values shall not differ more than four points between maximum and minimum.

(*b*) When desirable to vary the temperature, time and weight and, in order to provide for a uniform method of reporting results when variations are made, the samples shall be melted and cooled in air as above directed. They shall then be immersed in water or brine, as the case may require, for one hour at the temperature desired. The following combinations are suggested:

At 0° C. (32° F.) 200-g. weight, 60 seconds.

At 46.1° C. (115° F.) 50-g. weight, 5 seconds.

DISTILLATION TEST.

[A. S. T. M. Standard Test D20–16. With tentative revision in thermometer requirements recommended by committee D–4 in 1917.]

1. *Sampling.*—The sample as received shall be thoroughly stirred and agitated, warming, if necessary, to insure a complete mixture before the portion for analysis is removed.

2. *Dehydration.*—If the presence of water is suspected or known, the material shall be dehydrated before distillation. About 500 cc. of the material are placed in an 800-cc. copper still provided with a distilling head connected with a water-cooled condenser. A ring burner is used, starting with a small flame at the top of the still, and gradually lowering it, if necessary, until all the water has been driven off. The distillate is collected in a 200-cc. separatory funnel with the tube cut off close to the stopcock. When all the water has been driven over and the distillate has settled out, the water is drawn off and the oils returned to the residue in the still. The contents of the still shall have cooled to below 100° C. before the oils are returned, and they shall be well stirred and mixed with the residue.

3. *Apparatus.*—The apparatus shall consist of the following standard parts:

(*a*) Flask: The distillation flask shall be a 250-cc. Engler distilling flask, having the following dimensions:

Diameter of bulb	cm.	8.0
Length of neck	cm.	15.0
Diameter of neck	cm.	1.7
Surface of material to lower side of tubulature	cm.	11.0
Length of tubulature	cm.	15.0
Diameter of tubulature	cm.	0.9
Angle of tubulature	deg.	75

A variation of 3 per cent from the above measurements will be allowed.

(*b*) Thermometer: The thermometer shall conform to the following requirements:

It shall be made of thermometric glass of a quality equivalent to suitable grades of Jena or Corning make. It shall be thoroughly annealed. It shall be filled above the mercury with inert gas which will not act chemically on or contaminate the mercury. The pressure of the gas shall be sufficient to prevent separation of the mercury column at all temperatures of the scale. There shall be a reservoir above the final graduation large enough so that the pressure will not become excessive at the highest temperature. The thermometer shall be finished at the top with a small glass ring or button suitable for attaching a tag. Each thermometer shall have for identification the maker's name, a serial number, and the letters "A. S. T. M. Distillation."

The thermometer shall be graduated from 0 to 400° C. at intervals of 1° C. Every fifth graduation shall be longer than the intermediate ones, and every tenth graduation beginning at zero shall be numbered. The graduation marks and numbers shall be clear-cut and distinct.

The thermometer shall conform to the following dimensions:

Total length, maximum, 385 mm.
Diameter of stem, 7 mm.; permissible variation, 0.5 mm.
Diameter of bulb, minimum, 5mm.; and shall not exceed diameter of stem.
Length of bulb, 12.5 mm.; permissible variation, 2.5 mm.
Distance from 0° to bottom of bulb, 30 mm.; permissible variation, 5 mm.
Distance from 0° to 400°, 295 mm.; permissible variation, 10 mm.

The accuracy of the thermometer when delivered to the purchaser shall be such that when tested at full immersion the maximum error from 0 to 200° C. shall not exceed the following:

From 0 to 200° C	0°.5 C.
From 200 to 300° C	1°.0 C.
From 300 to 375° C	1°.5 C.

The sensitiveness of the thermometer shall be such that when cooled to a temperature of 74° C. below the boiling point of water at the barometric pressure, at the time of test, and plunged into free flow of stream, the meniscus shall pass the point 10° C. below the boiling point of water in not more than six seconds.

The thermometer shall be set up as for the distillation test, using water, naphthalene and benzophenone as distilling liquids. The correctness of the thermometer shall be checked at 0 and 100° C. after each third distillation until seasoned.

(*c*) Condenser: The condenser tube shall have the following dimensions:

Adapter	mm	70
Length of straight tube	"	185
Width of tube	"	12–15
Width of adapter end of tube	"	20–25

(*d*) Stands: Two iron stands shall be provided, one with a universal clamp for holding the condenser, and one with a light grip arm with a cork-lined clamp for holding flask.

(*e*) Burner and shield: A Bunsen burner shall be provided, with a tin shield 20 cm. long by 9 cm. in diameter. The shield shall have a small hole for observing the flame.

(*f*) Cylinders: The cylinders used in collecting the distillate shall have a capacity of 25 cc., and shall be graduated in 0.1 cc.

4. *Setting up the apparatus.*—The apparatus shall be set up as shown in figure 8, the thermometer being placed so that the top of the bulb is opposite the middle of the tubulature. All connections should be tight.

5. *Method.*—One hundred cubic centimeters of the dehydrated material to be tested shall be placed in a tared flask and weighed. After adjusting the thermometer, shield, condenser, etc., the distillation is commenced, the rate being so regulated that 1 cc. passes over every minute. The receiver is changed as the mercury column just passes the fractionating point.

The following fractions should be reported:

Start of distillation to 100° C.
110 to 170° C.
170 to 235° C.
235 to 270° C.
270 to 300° C.
Residue.

To determine the amount of residue, the flask is weighed again when distillation is complete. During the distillation the condenser tube shall be warmed when necessary to prevent the deposition of any sublimate. The percentages of fractions should be reported both by weight and by volume.

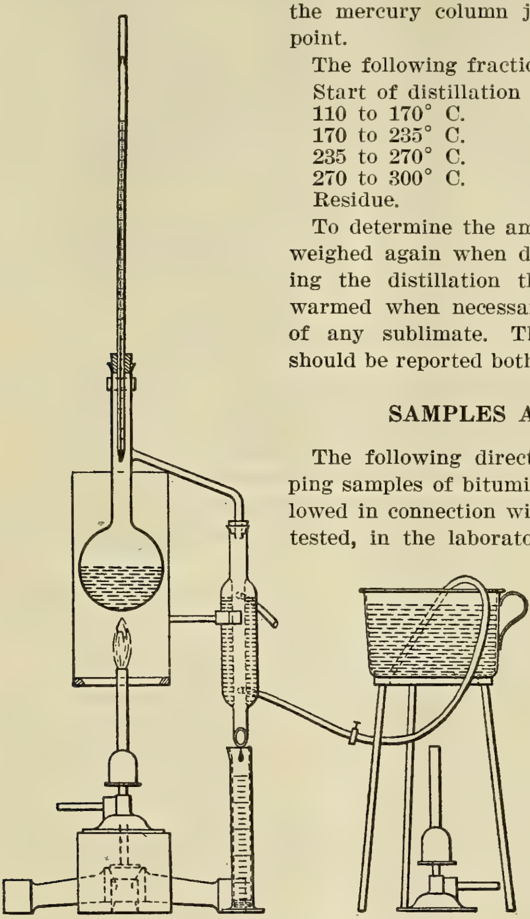

FIG. 8.—Distillation apparatus.

SAMPLES AND SAMPLING.

The following directions for selecting and shipping samples of bituminous materials should be followed in connection with materials which are to be tested, in the laboratory, for conformity with the foregoing specifications.

GENERAL DIRECTIONS.

(1) Samples should be taken so as to represent as nearly as possible an average of the bulk of material sampled and should also be selected with a view to ascertaining the maximum variation in characteristics which the material may possess. (2) Care should be taken that the samples are not contaminated with dirt or any other extraneous matter and that the sample containers are perfectly clean and dry before filling. (3) Immediately after filling, the sample containers should be tightly closed and properly marked for identification, the identification being placed on the container itself and not on the lid unless both container and lid are marked. (4) Samples should be packed for shipment in such manner that leakage of contents or contamination by excelsior, paper, or other packing material during transit is entirely prevented, as well as obliteration or removal of the identification marks. (5) Notification of shipment of samples, with statement of identification marks and such other descriptive information as may be necessary, should be promptly forwarded to the laboratory.

FREQUENCY OF SAMPLING.

(1) Each consignment of bituminous material should be sampled. (2) Additional samples should be taken whenever the material changes materially in

appearance or general character. (3) When the material is fluxed or maintained in heating kettles at an elevated temperature for periods of over 12 hours at least one sample should be taken and tested for consistency each day during its use.

INFORMATION ACCOMPANYING SAMPLES.

Whenever possible the following information should be furnished the laboratory in connection with each sample submitted.

1. Identification mark.
2. Name of material.
3. Name and address of producer.
4. To be examined for conformity with —— specification.
5. Name and location of road where material is to be used.
6. Proposed method of use or type of construction in which material is to be used.
7. Date sample taken.
8. Place sample taken.
9. Sample taken from (storage tank, tank car, barrel, drum, distributor or heating kettle).
10. Material shipped in (car No. —, Tank car No. —, barrels, drums, automobile distributor, or tank wagon).
11. Date shipped.
12. Date received at destination.
13. Date used or to be used if satisfactory.

TIME AND PLACE OF SAMPLING.

(1) Whenever practicable bituminous materials should be sampled at the point of manufacture, and at such time as to allow the tests, controlling acceptance or rejection, to be made in advance of shipment. (2) When impracticable to take samples at point of manufacture they should be taken from the shipment immediately upon delivery.

SIZE OF SAMPLES.

Samples of not less than one quart should be taken except that 3-ounce samples of asphalt cement or refined tar may be taken when the only test to be made is the penetration test or float test, as covered by direction No. 3 under “Frequency of Sampling.”

CONTAINERS.

(1) Containers for liquid bituminous materials should be 1-quart, small-mouth cans with screw cap or cork stopper. (2) Containers for semisolid and solid materials should preferably be 1-quart friction-top cans. (3) Samples of asphalt cement or refined tar which are to be subjected only to the penetration test or float test may be sent in 3-ounce round tin boxes with tight-fitting cover.

IDENTIFICATION OF SAMPLES.

(1) The container for each sample should carry a suitable mark which will clearly identify it in connection with additional information which should be furnished the laboratory. (2) For marking tin cans, a 10 per cent solution of silver nitrate may be used, provided the marking is allowed to thoroughly dry before the sample is packed. (3) Gummed labels may be used if the outside of the can is first scraped so as to present a rough surface upon which the label may be securely attached.

DRIP SAMPLES.

When loading tank cars, barrels, or drums from a storage tank, cooler, or still, drip samples may be taken. The material should be allowed to flow through the discharge pipe for a short time before the sample is taken and the drip valve should be so regulated that the operation of collecting the sample continues through the entire period of loading the containers.

SAMPLING FROM STORAGE TANKS AND TANK CARS.

(1) When the material is in a fluid condition three samples should be taken from each tank or tank car, one from the top, one from the bottom, and one from the center of the tank. The bottom sample may be taken from the discharge pipe through which a sufficient amount of the material is first allowed to flow so as to clean it properly. If there is no outlet at the middle of the tank a thief sample may be taken by lowering a closed bottle or can to the center of the tank and then removing the stopper or cover by means of a stout cord or wire to which it is attached. (2) Tank cars containing cold semisolid or solid bituminous material may be sampled through the dome by the use of a clean hot shovel.

SAMPLING FROM BARRELS AND DRUMS.

(1) Separate samples should be taken from not less than 3 per cent of the containers. (2) When the material is semisolid or solid samples should be taken at least 3 inches below the surface. A hatchet may be used if the material is hard and a broad stiff putty knife if the material is soft.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 692

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER July 23, 1918

THE AGRICULTURAL SPECIES OF BENT GRASSES.

Part I.—RHODE ISLAND BENT AND RELATED GRASSES.

By Charles V. Piper, *Agrostologist in Charge of Forage-Crop Investigations.*

Part II.—THE SEEDS OF REDTOP AND OTHER BENT GRASSES.

By F. H. Hillman, *Assistant Botanist, Seed-Testing Laboratories.*

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GENERAL SUMMARY.

Part I of this bulletin discusses the identity and characteristics of Rhode Island bent and the immediately related grasses, namely, redtop, fiorin, velvet bent, and "creeping bent." The distinguishing botanical and agricultural characteristics of these grasses are pointed out and two of them are illustrated with figures.

Three of these grasses have been handled commercially by seedsmen, namely, redtop, Rhode Island bent, and "creeping bent," in a mixture here referred to as South German mixed bent. The evidence indicates that little genuine Rhode Island bent seed has been on the market in recent years.

Rhode Island bent is a "very valuable grass for lawns and golf courses, not much inferior to creeping bent." Large quantities of seed

of this can be gathered from natural pastures in New England, and it is believed that the gathering and marketing of this seed will become an important resource, based entirely on the merits of the grass. In view of the fact that redtop seed can always be distinguished by an expert and the South German mixed bent can be distinguished by the incidental weed seeds present, there is good reason to believe that the industry of gathering Rhode Island bent seed and of establishing a large sale for it on its merits can be reestablished.

Part II of the bulletin discusses the seeds of the species of bent which occur in the trade. Conditions prevailing in the trade relating to the sale of redtop seed as seed of the finer bents and the importation of seeds of the finer bents under various and misleading names are set forth.

The characteristics by which seeds of certain of the kinds of bent can be distinguished are stated. Illustrations are given to make clear the statements made.

The principal impurities of domestic and of imported seed are illustrated in the belief that this information may be useful in distinguishing imported seed from that grown in this country.

The most important fact is that redtop seed can be distinguished from seed of Rhode Island bent and of South German mixed bent to the extent that the seed, either alone or mixed, can be detected with certainty.

The principal misbranding in the trade is the substitution of redtop seed for seed of one of the other bents, a procedure which will be discouraged by this bulletin.

With the information which this bulletin furnishes, it is believed that progressive seedsmen and others will promptly engage in the production of seed of the finer bent grasses.

Part I.—RHODE ISLAND BENT AND RELATED GRASSES.

By Charles V. Piper, *Agrostologist in Charge of Forage-Crop Investigations.*

INTRODUCTION.

"Rhode Island bent" as the name of a grass appeared in American agricultural literature at least as early as 1790 (4, p. 123)[1] and its modification "Rhode Island grass" as early as 1841 (17, p. 115). Perhaps no other grass has given rise to more confusion regarding its identity, both in commercial use and in botanical publications. The reason for this lies largely in the fact that many species and subspecies of bent grasses, the botanical genus Agrostis, are very similar to one another and consequently are much confused, even in botanical works.

The treatments by different botanists of the species and varieties centering about common redtop (*Agrostis alba* L. of most botanists) are much involved. Some of the confusion is due to the different opinions held by botanists as to the systematic value of the numerous forms described, but the matter has become more entangled by errors in the application of the names, both common and technical. The subject of botanical names is of interest primarily to botanists, but it has caused some confusion in the seed trade also and consequently in the culture of the bent grasses. The most noteworthy recent attempt to clarify the nomenclature is that of Ascherson and Graebner (1, p. 172–183). In Europe, however, many more varieties occur than in America, so the subject is correspondingly more complex.

From the agronomic standpoint it is necessary to consider only the forms which are utilized in agriculture or the seeds of which have been handled commercially. These forms are six in number, as follows:

Redtop (*Agrostis palustris* Huds.; *Agrostis alba* L. of most botanists), the most valuable species of bent for agricultural use. This grass is too coarse to make really fine turf. The commercial seed is grown in the United States, mainly in Illinois.

Fiorin (*Agrostis maritima* Lamarck; *Agrostis stolonifera* var. *latifolia* Sinclair), formerly a much-exploited grass, propagated vegetatively, the seed never having been gathered commercially. It occurs along the North Atlantic coast in America as well as in Europe.

Rhode Island bent (*Agrostis tenuis* Sibth.; *Agrostis vulgaris* With.), a much finer grass than redtop and probably the most abundant grass in New England, where it makes up much of the pastures. Commercial seed has been gathered principally in Rhode Island, but in recent years only to a very limited extent.

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[1] The serial numbers in parentheses refer to "Literature cited," p. 14.

Colonial bent. This is identical with Rhode Island bent, as is proved by cultures. Commercial seed has in recent years been gathered in small quantities in New Zealand.

Velvet bent, or brown bent (*Agrostis canina* L.), a distinct but variable European grass, sparingly introduced into the United States. Seed is always present in the bent seed gathered in Germany, here referred to as South German mixed bent, as velvet bent makes up a varying proportion of the turf grown from such seed. By an unfortunate error the name *Agrostis canina* has been associated with Rhode Island bent by recent writers, and this has caused much confusion.

Carpet bent. This grass is apparently always present in turf grown from South German mixed bent[1] seed. On turf 3 years old grown from such seed, carpet bent usually constitutes one-tenth to one-fourth of the turf. It produces long, creeping branches, so that each plant at length forms a dense circular mat of fine turf. The botanical name to be applied to carpet bent is still doubtful.

REDTOP.

Redtop (fig. 1) is now the common name employed for the most important of the bent grasses. In England, and formerly at least in New England, the names whitetop and white bent were used.

Redtop is the largest and most valuable of the grasses here described. Commercial seed has been grown for at least 40 years mainly in southern Illinois. The grass is, with scarcely a doubt, not indigenous to North America, but has been introduced from Europe.

Botanically, redtop is usually known as *Agrostis alba* L. The original specimens of Linnæus still preserved in his herbarium are of this grass, but his description and references apply partly to wood meadow grass (*Poa nemoralis* L.).

The name *Agrostis stolonifera* L. is also frequently applied to redtop, owing to some doubt concerning the type specimens in the Linnæan herbarium. Some botanists consider that this name really belongs to the grass also known as *Agrostis verti-*

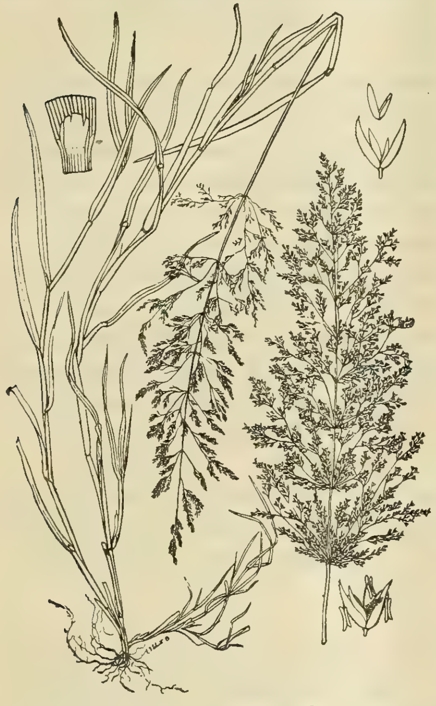

FIG. 1.—Redtop (*Agrostis palustris*). The detailed figures show the structure of the ligule, a spikelet in bloom, and separate parts of the spikelet.

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[1] South German mixed bent is often sold in the trade as "creeping bent," and usually under the scientific name *Agrostis stolonifera*. This name, the first binomial given to any grass of the group here discussed, belongs to a plant growing about Upsala, Sweden, there known as Kryp-hven, that is "creeping bent." It is quite intermediate in characteristics between redtop and fiorin, as determined from authentic Swedish specimens secured from Dr. Carl Lindman, of Stockholm, Sweden, but it is seemingly very different from carpet bent.

ciliata Vill., a noncultivated species mostly without stolons, because a specimen of that is in the Linnæan herbarium and because some of the references relate in part to the latter species; but the more conservative judgment of other botanists is that the name properly belongs with the stoloniferous grass that is native about Upsala, Sweden, there known as Kryp-hven.

In commercial use, and formerly also in botanical publications, appears the name *Agrostis dispar* Michaux, described from South Carolina. Hitchcock has examined Michaux's original specimen and pronounces it the same as ordinary redtop.

Agrostis capillaris is still another botanical name attached by some seedsmen to redtop. This name as used originally by Linnæus in 1762 is based on various older descriptions, including one of his own published in the Flora Lapponica in 1737. The evidence regarding the identity of this plant is much involved, and modern Swedish botanists no longer consider it to be a Scandinavian plant. In any event the evidence is clear that the name can not be applied to redtop.

The name marsh bent is also used occasionally in the seed trade, applied to redtop. This name apparently arose as an anglicizing of *Agrostis palustris* Huds., which, according to a letter from Dr. Otto Stapf, is based on a plant not distinguishable from *Agrostis alba* of Linnæus's herbarium. However, various English botanists use the name marsh bent in connection with a stoloniferous form.

Another common name applied to redtop, especially in the Southern States, and formerly at least in Pennsylvania, is herd's-grass. This name appears in agricultural literature as applied to redtop as early as 1804 (18, p. 192–202). Inasmuch as the name herd's-grass or herd-grass was applied in New England to timothy, botanical and agricultural writers have commonly pointed out that the herd's-grass of Pennsylvania and the Southern States is redtop. In Pennsylvania usage the name herd's-grass was applied both to *Agrostis alba* and to *A. vulgaris*, not only by agricultural writers, such as Mease (10), but also by the Pennsylvania botanist Muhlenberg (11, p. 69). Darlington (3, p. 10), however, restricts the name to *Agrostis vulgaris*. Herd's-grass is still a common name for redtop in the Southern States.

On the whole it would seem best to drop the name *Agrostis alba*, because it was founded partly on *Poa nemoralis*, and to use as the botanical name of redtop the next older name, *Agrostis palustris* Huds.

FIORIN.

Fiorin is the common name of an Irish grass which was much exploited as an agricultural crop by Dr. William Richardson, of Moy, Ireland, in the early part of the nineteenth century. This grass was recommended mainly for moor lands. It is characterized by its habit of forming long, creeping, leafy stolons, or runners, which often reach a length of 3 to 10 feet and grow until late in the season. From the accounts of the culture of this grass given by Richardson (14)[1] and others, it was propagated only in a vegetative manner, usually by scattering the stolons over the ground and covering slightly with soil. Apparently seed was rarely gathered or utilized, and there is no evidence that it ever entered into the seed trade.

From contemporary accounts, as well as from authentic preserved specimens, there is no doubt that this is one of the grasses that have been referred to *Agrostis stolonifera* L. There is doubt, however, as to whether it is exactly identical with Linnæus's original plant, which grows about Upsala, Sweden, and is there known as Kryp-hven.

The stoloniferous bents of Europe are a puzzling group, and some botanists describe as many as six different forms. Sinclair (15, p. 227–228, 343), who calls Richardson's fiorin *Agrostis stolonifera* var. *latifolia*, states that the varying results obtained by different experimenters were due in part to their growing different botanical varieties. Mackay (9, p. 298) states that he saw fine crops of fiorin on a reclaimed bog in Connemara, Ireland, the grass having been introduced three years previously with sand from the seashore. The grass was promptly tested in America, but never achieved any importance. A stoloniferous bent that occurs in America spontaneously is common along the seacoast from Delaware to Newfoundland, and by American botanists is usually designated *Agrostis alba* var. *maritima*, but it is not certain that it is native. A very similar grass occurs on the coasts of Oregon, Washington, and British Columbia, possibly introduced.

Whatever the exact botanical identity of fiorin may be, it is clearly distinct from both redtop and Rhode Island bent in its stoloniferous habit. The names creeping bent and stoloniferous bent, as used by English botanists, both refer to a grass with creeping stolons and properly do not apply to any form without stolons. The name fiorin has been used by modern seedsmen, however, in connection both with redtop and with South German mixed bent.

Fiorin is nowhere now cultivated in America, and apparently its culture in Europe did not long outlast Richardson's propaganda. It is not clear why this is the case, as numerous recorded experiments indicate that the grass is valuable for culture on moor lands. It is possible that the sale of redtop seed as fiorin may be partially responsible for the agricultural decadence of fiorin.

The stolon-producing bents are apparently constant in this habit. Stebler and Volkart (16, p. 115) state that the habit proved constant in their cultures, extending over many years. Sinclair (15, pp. 227, 230) records the same conclusion. This has also been the case in our limited experiments.

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[1] Richardson's writings were voluminous and appear in many of the agricultural journals of his time.

RHODE ISLAND BENT.

Rhode Island bent (fig. 2) is the most common and abundant grass on well-drained soils in New England and New York. It has every appearance of being a native, but it is highly probable that it was introduced from Europe, as it is not distinguishable from *Agrostis vulgaris* With., described originally from England.

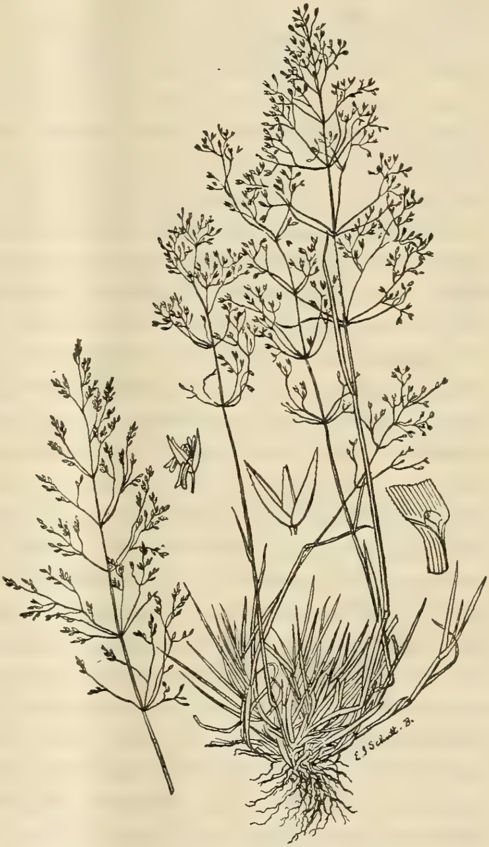

FIG. 2.—Rhode Island bent (*Agrostis tenuis*). The detailed figures show the ligule and a single spikelet.

There can be no doubt that this is the grass to which the name Rhode Island bent properly applies. Both the literary and traditional evidence clearly lead to this conclusion, which, however, has been obscured by the fact that many recent writers erroneously associated the name Rhode Island bent with *Agrostis canina* L., a grass rare in America.

It will suffice to point out that Flint (5, p. 18–20), in 1857, was perfectly familiar with both Rhode Island bent (*Agrostis vulgaris*) and white bent (*Agrostis alba*), the distinctive characters of which he contrasts.

Howard (7), before this, distinguished "*Agrostis vulgaris major*, large redtop, western redtop," from "*Agrostis vulgaris minor*, small redtop, finetop, etc.," but erroneously associated the name "Rhode Island, or Burden grass" with the former. Potter (13) in 1889 described the methods of saving seed of Rhode Island bent used by him on Prudence Island. On this island the common grass to-day is *Agrostis vulgaris*, while *Agrostis canina*, if it occurs there at all, is at least very rare.

The name redtop in New England commonly applies to *Agrostis vulgaris* and not to *Agrostis alba*, which formerly at least was known generally as white bent or whitetop.

Among the common names that have been applied in New England to Rhode Island bent are the following: Rhode Island grass, fine agrostis, fine bent, furzetop, Burden (or Burden's) grass, and small redtop.

Occasional plants of Rhode Island bent possess an awn to the floret. This form has been named *Agrostis alba aristata* Gray. It is much less common than the unawned Rhode Island bent, and Hitchcock (6) speaks of it as "scarcely more than a form of *Agrostis alba vulgaris*." This variety has never been cultivated except as its seed was indirectly mixed with true Rhode Island bent.

Agrostis alba aristata Gray breeds true or nearly so. Jenkins (8) reports an experiment in which nine plants were grown from awned seeds. In all cases the resultant plants had at least some of their florets awned, but in about one-third of the panicles there were but few awned florets, and in six panicles no awns could be detected.

The problem as to whether Rhode Island bent and its awned variety are native in America or were introduced from Europe is difficult. Their widespread abundance in New England argues in favor of their nativity, but other undoubtedly introduced perennial grasses are quite as widespread and abundant, such as Bermuda grass and Johnson grass in the South, bluegrass over much of the northeastern quarter of the United States, and velvet grass in the Pacific Northwest. To a less degree timothy, orchard grass, redtop, and other grasses show the same phenomenon.

If Rhode Island bent were native, it should show geographical continuity either northeastward through Labrador and Greenland or northwestward through Alaska. In the case of Old World plants undoubtedly native in New England, one or the other of these lines of natural distribution is evident. The distribution of Rhode Island bent does not accord with either of the two possible routes of natural spread, which argues in favor of the grass being introduced by man.

Prof. M. L. Fernald, of Harvard University, whose long and intimate knowledge of the northeastern American flora makes his testimony of special value, writes—

> I am now ready to state that *Agrostis vulgaris* is in all probability an introduced, though very extensively naturalized, grass. I can find no evidence of it in the more remote and essentially untrodden areas in the interior of Newfoundland or Gaspe, although in the neighborhood of settlements the plant has taken freely to primitive habitat. Variety *aristata* I should call unquestionably indigenous, though I have occasionally found it growing by roadsides or in the turf of lawns. Its chief habitats, however, are the absolutely untouched woodlands and thickets.

Rhode Island bent, by a curious and unfortunate misidentification, has for a long time been referred to both in seedsmen's catalogues and in botanical publications as *Agrostis canina* L. *Agrostis canina*, popularly known in England as brown bent, is sparingly introduced in America. It has never been handled pure in the seed trade, although its seed is a common impurity in seed of South German mixed bent.

The authority responsible for the identification of Rhode Island bent as *Agrostis canina* is obscure, but Beal (2, p. 151) adopted it in 1887, while Olcott (12, p. 179–180) in the same year mentioned the name with the following explanation:

> The botanic situation was complicated some 10 or 12 years ago by the well-meaning efforts of a Providence merchant—assisted by a botanist—to stem the tide of adulteration. This injured his own business and that of seed growers in the Narragansett country, who relied for a living on their sales of fine Agrostis seed under the trade name of Rhode Island bent. After what he considered a sufficient examination this worthy botanist declared that the systematic name of Rhode Island bent should be *Agrostis canina*, and this name was actually adopted in the lists of several eminent seedsmen.

This unfortunate error has continued both in commercial and botanical publications to the present day. As both the seed and other characters of brown bent are very distinct from Rhode Island bent, it is to be hoped that the error in due time will be generally recognized.

Rhode Island bent was formerly a grass of considerable commercial importance, but in recent years it has been little gathered. Seedsmen continue to include it in their lists, but the seed offered is nearly always redtop or South German mixed bent, or a mixture of these two. There were two reasons for the commercial decline of true Rhode Island bent: (1) The development of the redtop-seed industry in Illinois and (2) the importation of South German mixed bent seed. The seeds of these three are very much alike and can easily be substituted one for another. Redtop seed is much the cheapest of the three. For this reason it was often substituted wholly or in part for Rhode Island bent. Furthermore, redtop is more valuable for hay and pastures than Rhode Island bent, so that the use of the latter for these purposes declined. For fine lawns, however, Rhode Island bent is much superior to redtop.

Rhode Island bent makes a fine, close turf, scarcely inferior to that produced by South German mixed bent. At the time of writing (January, 1918) no seed of South German mixed bent is available, owing to conditions arising out of the European war. Rhode Island bent is, however, a very satisfactory substitute for use on lawns and golf courses, for which there exists a very large demand. Practically unlimited quantities of the seed could be gathered in New England and New York, and it is hoped that the conditions existing will bring about its commercial reestablishment. Even in competition with South German mixed bent there would continue to be a large demand for Rhode Island bent, so that the industry of gathering the seed should be permanent.

Rhode Island bent only rarely produces creeping stolons or runners, and these when present seldom exceed 6 inches in length. Single plants of Rhode Island bent rarely form patches of turf more than 6 inches in diameter.

Inasmuch as it seems advisable to drop the name *Agrostis capillaris* L., the name to be used should be the oldest one that undoubtedly belongs to Rhode Island bent. This is *Agrostis tenuis* Sibthorp, 1794, while *Agrostis vulgaris* With. dates from 1796. It is desirable that seedsmen use the name *Agrostis tenuis* in connection with Rhode Island bent, as *Agrostis vulgaris* has too commonly but erroneously been associated with redtop.

Rhode Island bent makes a very fine turf, dark green in color, and is apparently a pure strain in this respect. The seed may contain a small percentage of redtop, as this coarser grass is not rare in some New England pastures, but the percentage of redtop is seldom enough to be noticeable in the resultant turf.

From the practical standpoint of growing fine turf there is little reason to prefer any other bent to Rhode Island bent. The latter grass is so abundant in New England and New York that practically limitless quantities of seed could be gathered. With care, fields containing an appreciable quantity of redtop may be avoided, as when in bloom redtop is easily distinguished by its taller habit, broader leaves, coarser panicle, and longer ligule.

In view of these facts, it seems highly desirable that American seedsmen handle Rhode Island bent seed on its merits. There seems to be no reason why the New England seed can not be gathered at least as cheaply and probably more so than the South German mixed bent. It is not unlikely that special seed-gathering machines may be adapted or devised to further this industry. At present a vast quantity of this seed goes to waste, as even on well-grazed pastures the seed crop is little diminished.

COLONIAL BENT.

During the last few years seed from New Zealand has been put on the market under the names colonial bent and browntop. Turf and plants grown from this seed show it to be identical with Rhode Island bent.

VELVET BENT, OR BROWN BENT.

Velvet bent, or brown bent (*Agrostis canina* L.), is native to Europe but sparingly introduced into the United States. A small percentage of the seed commonly occurs in South German mixed bent. On putting greens seeded to the latter, the velvet bent can easily be detected by its forming very dense circular patches of a rather pale or apple-green color. The leaves are finer than those of carpet bent, usually 9 nerved, and under a lens are seen to be minutely roughened. The ligule is long. The patches of turf made by single plants of velvet bent are often a foot or more in diameter and make what is probably the finest of all grass turfs. Under the conditions at Washington, D. C., velvet bent rarely forms seeds, the flowers being replaced by propagula resembling bunches of small leaves, which propagate the plant vegetatively. When grown alone, velvet bent forms much-branched stolons 4 or 5 inches long and often with dense masses of leaves at the tip. This character does not appear in closely clipped turf.

A source of a supply of seed of this grass is a great desideratum, as the turf it makes is of such exquisite quality and beauty of appearance.

CARPET BENT.

Carpet bent is one of the most desirable turf plants that always occurs in turf grown from South German mixed bent seed. Seedsmen commonly label South German mixed bent seed *Agrostis stolonifera* and use such common names as creeping bent, South German fiorin, and stoloniferous bent grass.

The only source of supply of commercial seed has been southern Germany. It is said to have been gathered from natural areas of grass and not specially planted for seed production.

Most of the plants grown from South German mixed bent seed are apparently identical with Rhode Island bent. The leaves have short ligules, and when grown to maturity the plants are indistinguishable from Rhode Island bent.

In old plantings of South German mixed bent, especially on putting greens, at least four forms of turf may usually be distinguished: (1) Bright green very fine-leafed circular patches, (2) dark green larger circular patches, (3) blue-green similar patches, and between these (4) medium green turf not in definite patches. The bright green very fine-leafed plant is velvet bent (*Agrostis canina*). The grass that does not form definite patches is probably nearly all Rhode Island bent. The other two sorts that form circular mats are forms of what is here called carpet bent.

When portions of these last two are planted alone they produce creeping runners 3 or 5 feet long the first season, making circular mats 5 to 7 feet in diameter, and with relatively few flowering culms. It is by this stoloniferous character that carpet bent is most strikingly distinguished from Rhode Island bent, but the ligules are long and the flowering panicles rather dense.

Experiments are now under way to test turf grown from different forms of carpet bent by vegetative multiplication. It is found very easy to plant by cutting the long runners into pieces 2 to 3 inches long. This method is entirely practicable where a uniform fine quality of turf is desired. One plant 6 feet in diameter will give enough cuttings to sow an area 30 feet square. Such pure strains avoid the particolor effect so characteristic of greens seeded to South German mixed bent.

The botanical name to be applied to carpet bent is not yet certain.

SUMMARY.

(1) Rhode Island bent is a very common grass in New England and New York and less common west to Michigan and south to Virginia. The evidence points clearly to its being an introduction from Europe.

(2) Rhode Island bent seed was formerly gathered in considerable quantities, mainly in Rhode Island, but in recent years very little of the genuine seed has reached the market.

(3) The commercial decline of Rhode Island bent seed seems to be correlated with the development of the redtop-seed industry in Illinois. Redtop seed is cheaper and therefore was substituted for Rhode Island bent by dealers.

(4) Rhode Island bent is an excellent grass for fine turf, and for this purpose is excelled only by velvet bent and carpet bent.

(5) Rhode Island bent seed could be gathered nearly pure in almost unlimited quantities from old pastures in New England and New York. By the use of labor-saving machinery the seed should be harvested cheaply enough to command a large market.

(6) Colonial bent, or browntop, the seed of which is gathered in New Zealand in small quantities, is the same as Rhode Island bent.

(7) The botanical names of Rhode Island bent and the related grasses, redtop, fiorin, creeping bent, and velvet bent, have been much confused. Some of the common names also have been erroneously interchanged. The name fiorin really belongs to a grass formerly cultivated that possesses long, creeping, leafy runners and was propagated solely by these runners, the seed never having been handled commercially. This name therefore should not be used either for redtop or for Rhode Island bent. The name *Agrostis canina* belongs to velvet bent and should not be applied to Rhode Island bent, which botanically is *Agrostis tenuis*.

(8) Carpet bent (*Agrostis* sp. indet.) and velvet bent (*Agrostis canina* L.) make up much of the turf on 3-year-old lawns grown from South German mixed bent seed. This mixed seed constitutes at present the only commercial supply of these two fine bents.

(9) Redtop and fiorin produce rather coarse turf as contrasted with the three fine bents. Of the latter, velvet bent makes the densest, finest turf and carpet bent the next best, while Rhode Island bent is slightly coarser. All these, however, either alone or in mixture, make the finest, smoothest turf of all northern lawn grasses.

(10) It is recommended that seedsmen employ the following common and scientific names for the grasses described in this bulletin.

Redtop—*Agrostis palustris* Huds.
Rhode Island bent—*Agrostis tenuis* Sibth.
Colonial bent—*Agrostis tenuis* Sibth.
Velvet bent—*Agrostis canina* L.
South German mixed bent—*Agrostis spp.*

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Part II.—THE SEEDS OF REDTOP AND OTHER BENT GRASSES.

By F. H. Hillman, *Assistant Botanist, Seed-Testing Laboratories.*

INTRODUCTION.

It is important that the seed of redtop be distinguished from that of other bent grasses which have finer leaves and stems, because it is often sold as seed of the latter. Redtop seed has been imported from Europe as seed of the finer bent grasses, and more rarely the latter has been imported as seed of redtop.

The seed of common redtop (*Agrostis palustris* Huds.; *Agrostis alba* L. of most botanists) is mostly produced in southern Illinois. The seed of Rhode Island bent (*Agrostis tenuis* Sibth.), a very abundant grass in New England and New York, formerly was gathered in commercial quantities, but little, if any, of it has been in the market in recent years. Colonial bent seed has been received from New Zealand. Plants grown from this seed have proved to be *Agrostis tenuis* and therefore botanically identical with Rhode Island bent. The seed of South German mixed bent, believed to be produced in southern Germany only, has been imported from different points in Europe and from England. ''South German mixed bent'' is not a trade name, but it is used in this bulletin to avoid confusion with the trade names in use. This seed is a mixture of the seed of redtop, velvet bent (*Agrostis canina* L.), and one or more undetermined species or varieties of bent.

TRADE CONDITIONS.

The relation to each other of the kinds of seed under discussion as they appear in the trade is essentially as follows: American-grown redtop seed is not likely to have mixed with it seed of the other bent grasses. Rhode Island bent seed, now at least rare in the market, is likely to contain some seed of redtop, since the latter grass is common where the Rhode Island bent prevails. Seed of velvet bent (*Agrostis canina*) does not occur in the trade as pure seed, and but rarely as a predominating ingredient of South German mixed bent seed. It appears to enter the American trade only through the imported seed produced in southern Germany.

The samples of colonial bent which the writer has seen contained considerable chaff, but the bent seed was the purest *Agrostis tenuis* that has come under his observation. Seed of South German mixed bent, imported under one name or another, exhibits the impurities characteristic of seed produced in Europe, and in this way can be distinguished from seed grown in this country when considered in bulk quantity. This seed has been imported under the names *Agrostis stolonifera*, *Agrostis canina*, creeping bent, South German agrostis, South German fiorin, or some similar name, and as Rhode Island bent.

One hundred samples of seed imported under some one of the above names or a similar name and taken at random from among custom-house samples representing importations prior to 1915 were labeled as follows: "*Agrostis stolonifera*," 54 samples; "*Agrostis canina*," 27 samples; "creeping bent," 9 samples; "South German fiorin," 3 samples; "German fiorin," 2 samples; "German agrostis," 2 samples; "Rhode Island bent," 2 samples; and "True German agrostis," 1 sample. Of these samples, 5 consisted of redtop only, while 25 contained redtop as the principal ingredient. In the remaining 70 samples, seed of the finer bent grasses predominated. Seed of velvet bent was present in each of the 95 samples, and in some this appeared to amount to as much as 40 per cent or more of the mixture. The remaining undetermined fine bent seed in these lots predominated in most of the 70 samples.

From a wider range of samples of imported seed, 27 were found to consist of redtop only. But 4 of these samples were imported as redtop, the others being labeled as follows: "*Agrostis stolonifera*," 9 samples; "creeping bent," 5 samples; "grass seed," 5 samples; "fancy agrostis," 2 samples; "*Agrostis canina*," 1 sample; and "*Agrostis vulgaris*," 1 sample. Careful examination of these samples of redtop seed failed to show any evidence that the seed was produced in Europe, and good reasons appeared for believing that it was grown in this country. Instances were also noted of the entry of seed of the finer bents, labeled "redtop."

The importations of Agrostis during 1916 represented 48 lots, totaling 46,663 pounds. Two lots amounting to 1,508 pounds consisted of redtop only. One lot only, of 3,900 pounds, was South German mixed bent seed. The remaining 45 lots, totaling 41,255 pounds, came from a single firm in Arnheim, Holland. The seed in each of these lots was chiefly redtop, together with South German mixed bents varying in quantity from a mere trace to an appreciable proportion. Of the 48 lots imported in 1916, 27 were entered as "creeping bent," 17 as "Rhode Island bent," 2 as "*Agrostis canina*," 1 as "*Agrostis stolonifera*," and 1 as "redtop." One of the two lots of redtop was imported as "redtop"; the other as "creeping bent." The single lot of South German mixed bent seed was imported as "Rhode Island bent."

Owing to the European war no importations of South German mixed bent seed were made in 1917 or prior to March 6, in 1918, the date of this writing.

DISTINGUISHING THE SEEDS.

In consequence of the close relationship existing between redtop and the other bent grasses, their seeds are very similar in appearance and are readily mistaken, one kind for another, unless they are examined critically with the aid of a low-power compound microscope or a high-power hand lens.

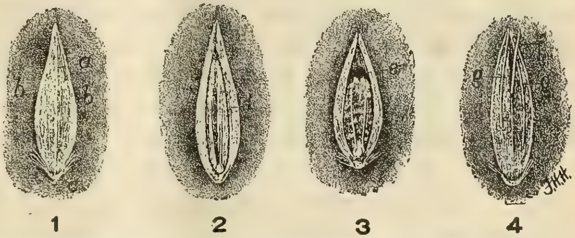

FIG. 3.—Hulled seeds of redtop (*Agrostis palustris*), enlarged, illustrating the general structure of seeds of bent grasses: 1, Back of the lemma; *a*, the keel vein; *bb*, the marginal veins; *c*, the callus. 2 and 3, The opposite side of the seed; *d*, the palet, not wrinkled and covering the grain; *e*, the palet, wrinkled and shorter than the grain. 4, Back of a lemma having an awn (*f*) and intermediate veins (*gg*).

The distinguishing characters of the minute seeds of redtop and other bent grasses which are of practical value in recognizing the species are found in the seeds when freed from the outer enveloping chaff (fig. 3). This chaff (fig. 4) readily separates from well-matured seeds. In immature seeds the chaffy scales tend to cling to each other and to the inclosed seed. An unnecessary proportion of chaff usually constitutes a considerable part of the bulk of Rhode Island bent, colonial bent, and South German mixed bent seed. Domestic redtop is sold with the chaff present as "chaffy" redtop and free of the chaff as "fancy," "hulled," or "recleaned" redtop.

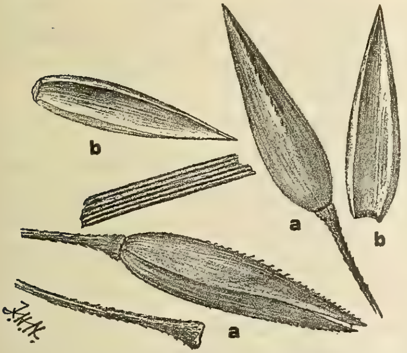

FIG. 4.—Chaff, or hull, of redtop seed: *a*, Whole spikelets usually devoid of seed in "chaffy" grades; *b*, separated scales of the same; *a* and *b* represent the outer chaff of the seed. (Enlarged.)

An opinion on the kind of seed found in a given sample and its probable source is based upon (1) the structural characters of the seed, which show its kind, and (2) the impurities found in the sample, such as other grass seeds, weed seeds, and chaff, which usually indicate the source of production.

GENERAL STRUCTURE.

Freed from the two outer chaffy scales, called the glumes, an individual seed of redtop or of the other bent grasses consists of a grain lying between two unequal, more or less inclosing scales (fig. 3, *1* and *2*). The larger scale, which exceeds the length of the grain, is termed the lemma. The smaller is termed the palet or palea. The palet is especially important in distinguishing the kind of seed. While the palet varies somewhat in the same kind of seed, it differs greatly in seed of certain different kinds. The base of the seed has a collarlike thickening, the callus, which sometimes bears a few bristlelike white hairs. The apex of the seed is pointed and three angled or four angled, depending upon the number of veins at the apex of the lemma.

The lemma has at least three evident longitudinal veins, one near each margin, the marginal veins, and one in its center, the keel vein (fig. 3, *1*). These veins produce the 3-angled form of the apex of the lemma. Often the keel vein does not develop to the apex of the lemma, and it sometimes develops into a bristle, or awn, projecting from the keel of the lemma (fig. 3, *4*). In either event two additional veins, the intermediate veins, appear between the keel and marginal veins. The intermediate and marginal veins then give the apex of the lemma a 4-angled form. The lemma is thin and usually translucent at the apex, becoming thicker and opaque toward the base. The translucent portion of the lemma gives the seed of some species a silvery white appearance.

The palet has two longitudinal veins if sufficiently well developed (fig. 3, *2* and *3*). It is very thin, often translucent and showing the darker grain beneath, sometimes transparent and obscure. It varies in size and texture and in its tendency to be free from or adherent to the grain.

The grain usually is reddish brown, oblong in outline, and finely wrinkled at maturity. The interior, or endosperm, may be dry and somewhat resistant to pressure on crushing, or it may be semifluid and soft when crushed, depending on the species of the seed.

DISTINGUISHING CHARACTERS.

The distinguishing characters of the hulled seeds of redtop and the other commercial bent grasses appear in the comparative size and form of the seed, the texture and surface markings of the lemma, the character of the awn, the length of the palet compared with the length of the lemma and of the grain, its texture and degree of adhesion to or its freedom from the grain, the size and consistency of the grain, the associated weed seeds and other seeds, and the character of the chaff, if present.

In practical seed analysis, small bulk samples of commercial seed of redtop, Rhode Island bent, colonial bent, and South German mixed bent can be distinguished one from another. The velvet-bent seed in the South German mixed bent seed can be distinguished and its true proportion determined. In mixtures of the commercial kinds determination within 5 per cent of the true proportions of redtop seed and seed of the fine bent grasses taken collectively can be made. The seed of the fine bent grasses found in South German mixed bent seed, exclusive of the velvet-bent seed it appears always to contain, can not at present be identified with certainty or distinguished by the seed alone from American-grown Rhode Island bent seed and colonial bent seed. Finally, the seed of carpet bent or strictly stoloniferous forms of bent can not be recognized at present. These phases of the subject are open to further investigation.

The commercial kind of seed is often suggested and sometimes determined by evidence of its source of production which appears in the associated weed seeds and other seeds found in the sample. Though certain kinds of weed seeds are found in both domestic and imported seed, others are strongly suggestive either of domestic or of foreign production. In this matter, the absence of certain kinds of seeds is as helpful as the presence of others.

THE SEEDS DESCRIBED.

The following descriptions of the seeds of redtop, Rhode Island bent, and velvet bent are based chiefly upon their appearance under a low-power compound microscope. When the distinguishing characters are recognized by this means the use of a high-power hand lens enables one to recognize with a considerable degree of accuracy the kinds in bulk quantity or in mixtures. A complete qualitative and quantitative analysis requires the use of a compound microscope and of laboratory methods.

SEED OF REDTOP (AGROSTIS PALUSTRIS HUDS.; AGROSTIS ALBA L. OF MOST BOTANISTS).

Lemma 0.05 to 0.08 of an inch in length, lanceolate to lanceolate-oblong in outline, somewhat glistening, the longest lemmas exceeding the grain about one-third their length, the upper third or half of the lemma translucent and silvery white, the lower part opaque and often straw colored, the apex usually distinctly three angled, occasionally four angled by the absence of the keel vein; the surface glabrous, very finely and longitudinally striate; the awn occasional, rudimentary, straight, not spirally twisted, rarely exceeding the apex of the lemma or bent and twisted, arising near the apex of the lemma, rarely as low as the middle of the latter, often a mere projection from the surface (fig. 3, *4*); hairs at the callus present or wanting; palet exhibiting two types in appearance: (1) Not wrinkled, scarcely translucent, evidently striate, usually equaling or exceeding the grain (fig. 3, *2*); (2) wrinkled, often shorter than the grain and between two-thirds

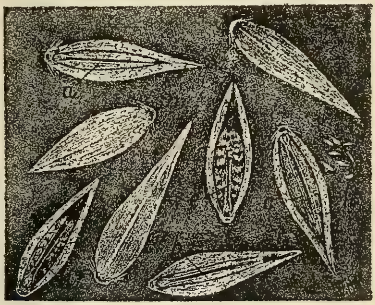

FIG. 5.—Seeds of redtop (*Agrostis palustris*), enlarged and natural size: In seeds *a*, *b*, and *c* the palet is not wrinkled and covers the grain. In seeds *d* and *e* the palet is wrinkled and shorter than the darker grain. (The natural size is shown at *f*.)

and three-fourths the length of the lemma, rarely but half the length of the grain, obscurely striate, translucent, showing the grain, more or less adherent to the grain, rarely wholly adherent and transparent and therefore obscured till separated from the grain (fig. 3, *3*); veins of the palet often distinct, sometimes scarcely evident; grain oblong in outline, often robust, mostly reddish brown and finely wrinkled, dry and mealy when crushed under slight pressure (fig. 5).

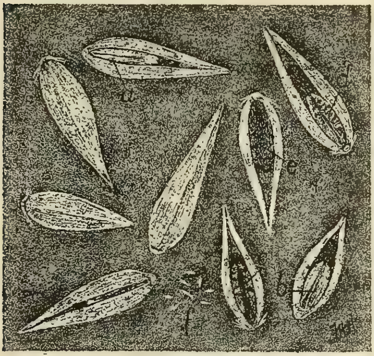

FIG. 6.—Seeds of Rhode Island bent (*Agrostis tenuis*), enlarged and natural size. In seeds *a* and *b* the palet is not wrinkled. In seeds *c* and *d* the palet is wrinkled and translucent. In seed *e* the transparent, closely adherent palet is obscured against the darker grain. (The natural size is shown at *f*.)

SEED OF RHODE ISLAND BENT (AGROSTIS TENUIS SIBTH.; AGROSTIS VULGARIS WITH.).

Lemma 0.04 to 0.07 of an inch in length, ovate-lanceolate to narrowly lanceolate in outline, narrowly pointed at the apex, exceeding the grain by one-fourth or less of its length, not glistening, the upper half or more of the lemma translucent and silvery white, opaque toward the base; the surface of the lemma glabrous and finely striate longitudinally; the apex of the lemma usually distinctly three angled; an aborted awn occasional from near the apex or rarely not lower than the middle of the lemma, straight, not spirally twisted, rarely equaling the apex of the lemma, such awn-bearing lemmas sometimes four angled at the apex; seeds of some plants all or nearly all bearing similar awns, each awn arising between one-fourth and one-third the length of the lemma from its base, the awn bent near the apex of the lemma and spirally twisted below the bend; the lemmas thus awned four veined at the apex (fig. 7); palet sometimes not wrinkled, semitranslucent and striate, rarely equaling the grain, usually clearly shorter than the grain, between one-half and two-thirds the length of the lemma, or often scarcely exceeding half the length of the grain, usually wrinkled and partially adherent to the grain, often wholly adherent and transparent and therefore obscured till separated from the grain; veins of the palet commonly wanting; grain slenderly oblong in outline, dry and mealy when crushed. (Figs. 6 and 7.)

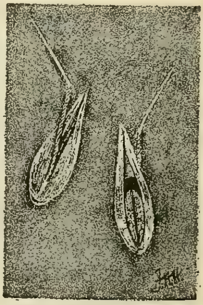

FIG. 7.—Seeds of the awned form of Rhode Island bent (*Agrostis tenuis*). (Enlarged.)

Compared with seeds of redtop, the seeds of Rhode Island bent are, in general, more slender, smaller, less glistening, and lighter colored;

the lemma and palet are thinner, somewhat more translucent, the palet more frequently adherent to the grain and transparent. The palet is distinctly smaller than is usual in redtop and shorter in proportion to the length of the lemma. The nonwrinkled, striate, often opaque palet, which commonly equals or exceeds the grain in redtop, is conspicuously rare in seeds of Rhode Island bent. Seeds bearing a twisted, bent awn from near the base, common in Rhode Island bent seed, are absent in redtop. The grain in Rhode Island bent-grass seed is somewhat smaller and more slender than in redtop.

Seeds of colonial bent (*Agrostis tenuis*) present all the characteristics observed in the seeds of Rhode Island bent.

SEED OF VELVET BENT (AGROSTIS CANINA L.).

Lemma 0.04 to 0.07 of an inch in length, ovate-lanceolate or elliptical in outline, exceeding the grain from slightly to one-fourth its length; surface usually minutely granular, obscuring the faint longitudinal striation; surface dull and pale straw colored or apparently darker, due to the grain appearing through the lemma, which often is translucent except at the opaque base; hairs at the callus present or wanting; many seeds awned, the awn varying from a mere projection from the surface to a long bristle exceeding the lemma, bent near the apex of the latter and spirally twisted below the bend, many of the intermediate forms straight and not twisted, the awns mostly arising near the middle of the lemma, the longest ones occasionally arising as low as one-fourth of the length of the lemma from its base; apex of the lemma four veined, owing to the absence of the keel vein above the middle of the lemma; palet a minute, obscure scale of subequal length and width, appearing as a whitish spot at the base of the grain; grain usually smaller than in redtop or Rhode Island bent, its surface more or less exposed between the margins of the lemma, soft, and under slight pressure exuding the semifluid endosperm. (Fig. 8.)

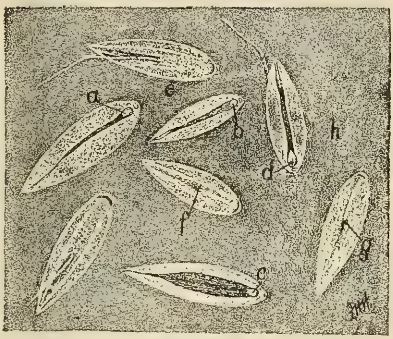

FIG. 8.—Seeds of velvet bent (*Agrostis canina*), enlarged and natural size. Seeds *a*, *b*, *c*, and *d* exhibit the minute palet. Well-developed awns appear at *d* and *e*. Rudimentary awns are indicated at *f* and *g*. A much-exposed grain is shown at *c*. (The natural size is shown at *h*.)

A greater proportion of the seeds of velvet bent are small than is the case in redtop or Rhode Island bent. The ovate-lanceolate or elliptical outline, the dull granular surface, the large proportion of awned seeds, the absence of an evident palet, and finally the soft semifluid grain serve readily to distinguish these seeds from those of redtop, Rhode Island bent, and colonial bent. By the same means, the seeds of velvet bent can be recognized when occurring in South German mixed bent seed.

IMPURITIES OF COMMERCIAL SEED.

An examination of many commercial samples of the seeds of redtop and of South German mixed bent shows that their origin, whether domestic or foreign, can usually be determined. The studies of the writer in this connection include domestic redtop seed, redtop imported from Europe, South German mixed bent seed imported from Germany, Holland, and England, and a limited number of samples of Rhode Island bent seed from Rhode Island and of colonial bent seed from New Zealand. The samples of domestic redtop seed and of South German mixed bent seed examined were sufficient in number to show the prevailing kinds of incidental seeds occurring with these commercial seeds. A smaller number of samples of redtop seed known to have been imported from Europe, 27 in all, represented all that were available. The result of the examination of the samples of Rhode Island bent seed is supported by observations by the writer of the various plants occurring in fields in Rhode Island, where the Rhode Island bent grass grows abundantly.

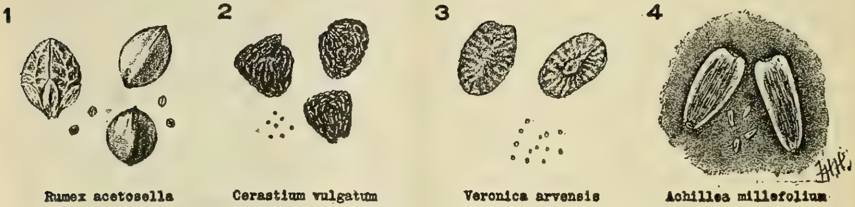

FIG. 9.—Seeds occurring frequently in both American-grown redtop seed and South German mixed bent seed (enlarged and natural size): 1, Sorrel (*Rumex acetosella*); 2, mouse-ear chickweed (*Cerastium vulgatum*); 3, corn speedwell (*Veronica arvensis*); 4, yarrow (*Achillea millefolium*).

Among the incidental seeds found in domestic redtop seed and in South German mixed bent seed certain kinds are common to both. This is to be expected, since these incidental seeds occur commonly with other kinds of commercial seed of both domestic and foreign origin, owing to the cosmopolitan character of their plants. Four of the kinds found most frequently are shown in figure 9. Exclusive of these kinds, others are confined almost wholly to the domestic redtop seed (fig. 10), and still others are confined to the South German mixed bent seed (fig. 11).

The plants represented by some of the kinds of seed considered characteristic of European-grown seed are known to occur in this country, but their distribution and the conditions of their growth are not such as to lead to the presence of their seed in domestic seed to the extent that they appear in the imported seed. Furthermore, the absence from domestic seed of seeds characterictic of imported seed and the absence from imported seed of seeds characteristic of domestic seed afford additional evidence of the origin of the seed in question. It was by the presence of certain kinds of seeds and by the absence of others that the 27 samples of imported redtop seed were determined to be of American origin.

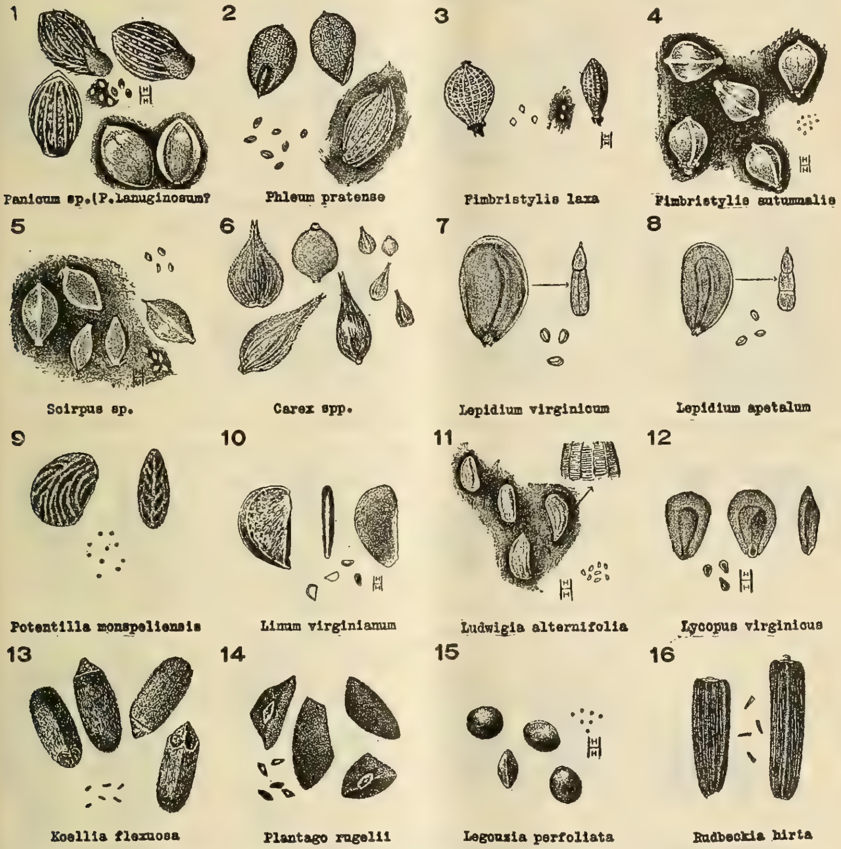

FIG. 10.—Seeds characteristic of American-grown redtop seed and Rhode Island bent seed (enlarged and natural size): 1, Panic grass (*Panicum* sp.); 2, timothy (*Phleum pratense*); 3, *Fimbristylis laxa*; 4, *Fimbristylis autumnalis*; 5, club rush (*Scirpus* sp.); 6, sedges (*Carex* spp.); 7, peppergrass (*Lepidium virginicum*); 8, peppergrass (*Lepidium apetalum*); 9, cinquefoil (*Potentilla monspeliensis*); 10, wild yellow flax (*Linum virginianum*); 11, rattlebox (*Ludwigia alternifolia*); 12, bugleweed (*Lycopus virginicus*); 13, mountain mint (*Koellia flexuosa*); 14, black-seeded plantain (*Plantago rugelii*); 15, Venus's-looking-glass (*Legouzia perfoliata*); 16, black-eyed Susan (*Rudbeckia hirta*).

Some of the lots of seed imported as South German mixed bent consisted largely of redtop, and in some instances this redtop seed is strongly suspected of being American seed that had been added to the bent seed. This is consistent with the fact that 18 of the 27 samples of imported American-grown redtop seed were brought to this country as South German mixed-bent seed under some trade name in common use, only 4 of the total number being entered as redtop seed.

The samples of Rhode Island bent seed examined may be considered fairly representative of New England grown seed which has not been recleaned. Several kinds of incidental seeds which are characteristically American were found in these samples. Furthermore, the weed seeds characteristic of South German mixed bent seed were absent from these samples. They contained no seed of velvet bent (*Agrostis canina*), which has been found in every lot of South German seed examined.

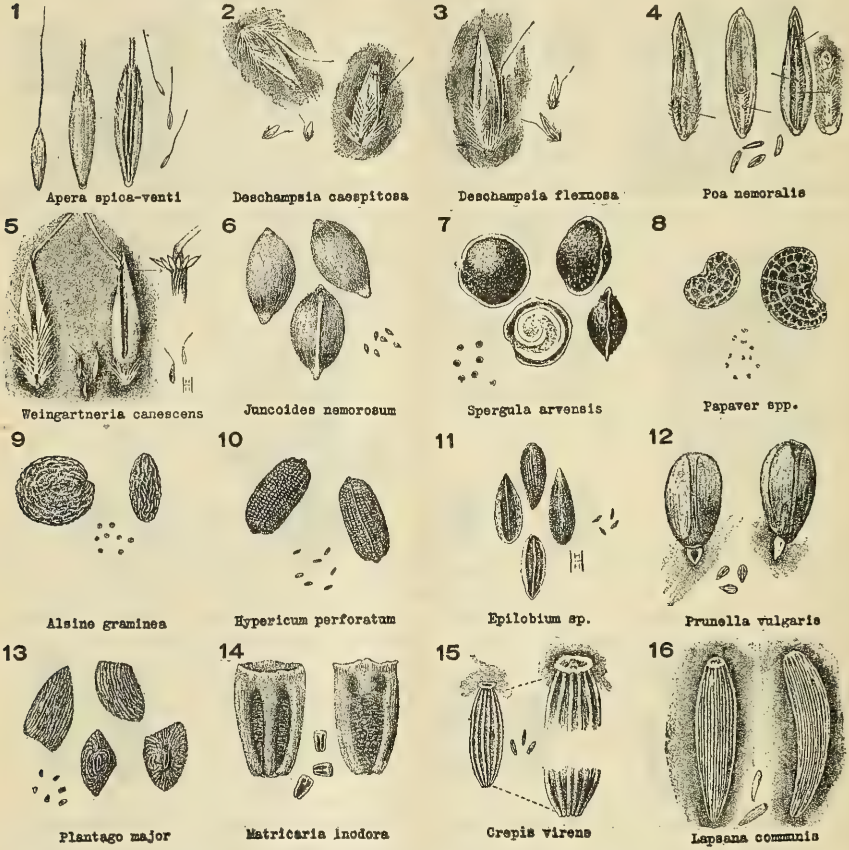

FIG. 11.—Seeds characteristic of South German mixed bent seed (enlarged and natural size): 1, Silky bent grass (*Apera spica-venti*); 2, tufted hair-grass (*Deschampsia caespitosa*); 3, wavy hair-grass (*Deschampsia flexuosa*); 4, wood meadow grass (*Poa nemoralis*); 5, *Weingartneria canescens*; 6, wood meadow rush (*Juncoides nemorosum*); 7, spurry (*Spergula arvensis*); 8, poppy (*Papaver* spp.); 9, starwort (*Alsine graminea*); 10, St. John's-wort (*Hypericum perforatum*); 11, willow herb (*Epilobium* sp.); 12, heal-all (*Prunella vulgaris*); 13, plantain (*Plantago major*); 14, scentless camomile (*Matricaria inodora*); 15, fireweed (*Crepis virens*); 16, nipplewort (*Lapsana communis*).

The samples of colonial bent seed were too few to afford specific conclusions as to the range of the characteristic incidental seeds occurring with this seed; but certain kinds found are different from those occurring with seed of redtop or fine bents from other sources.

SUMMARY.

(1) Seed of the bent grasses occurring or likely to occur in the trade consists of (1) redtop mostly produced in Illinois; (2) Rhode Island bent mostly gathered in Rhode Island, but in recent years scarce in the American market; (3) colonial bent from New Zealand; and (4) South German mixed bent, imported under various names from Europe.

(2) The seed of redtop is the cheapest of the kinds of bent seed and often is substituted wholly or in part for the others.

(3) The seed of redtop in the domestic trade is chiefly, if not wholly, of domestic production and is free from seed of Rhode Island bent, colonial bent, and South German mixed bent.

(4) The seed of Rhode Island bent is American grown and likely to contain some seed of redtop; but it appears never to contain seed of velvet bent.

(5) The seed of colonial bent imported from New Zealand recently has appeared in this country. This seed is botanically identical with that of Rhode Island bent. The samples examined contained little or no redtop seed and were free from velvet bent.

(6) South German mixed bent seed is produced in southern Germany and has been imported for the American trade. Owing to the European war, but one importation of this seed was received in 1916 and none in 1917. It consists of a mixture of redtop seed, velvet-bent seed, and seed of undetermined fine bent, which usually predominates.

(7) The seed of redtop can be distinguished by the seed alone from that of Rhode Island bent, colonial bent, and the fine bent of South German mixed bent seed.

(8) Rhode Island bent seed can be distinguished from South German mixed bent seed and colonial bent seed chiefly by means of the incidental seeds of weeds and cultivated plants present.

(9) Individual seeds of Rhode Island bent apparently are indistinguishable from individual seeds of the undetermined fine bent found in South German mixed bent seed.

(10) South German mixed bent seed can be identified by the incidental seeds present and by the seed of velvet bent (*Agrostis canina*) it contains.

(11) Seed of velvet bent can be recognized, and its quantity in a sample of South German mixed bent seed can be determined accurately.

(12) Seed of carpet bent or that of any strictly stoloniferous form of bent can not be recognized at present, so far as is known.

(13) Redtop seed has been imported as South German mixed bent seed, presumably to be sold as the latter. Much of this seed, at least, was evidently American grown.

(14) Seed of South German mixed bent has been imported under several different names, which are not only confusing but in part are specifically incorrect and misleading.

(15) In some instances excellent South German mixed bent seed has been imported under the names of redtop and Rhode Island bent.

(16) The general condition of the domestic trade relating to the seed of the finer bent grasses is unreliable.

(17) The principal misbranding in the trade, and the most important to the buyer, is the sale of redtop seed for seed of the finer bents.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 693
Joint Contribution from the Office of Farm Management,
W. J. SPILLMAN, Chief, and the Bureau of
Plant Industry, W. A. Taylor, Chief.

Washington, D. C. PROFESSIONAL PAPER July 16, 1918

FARM PRACTICE IN GROWING SUGARBEETS FOR THREE DISTRICTS IN UTAH AND IDAHO, 1914–1915.

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The data presented in this bulletin are based upon 173 farm estimates. Three typical districts are represented in this study, namely, Provo, in Utah County, Utah; Garland, in Boxelder County, Utah; and Idaho Falls, in Bonneville County, Idaho. The observations which were made are directly applicable to the crop years 1914 and 1915. At Provo and Garland practically all of the farmers who gave estimates during the year 1914 also contributed information for the crop year beginning April 1, 1915.

SUMMARY OF RESULTS.

The most important differences in the field practice employed in the three areas studied were found in such operations as manuring, plowing, disking, harrowing with the spring-tooth, cultivating (some using a 1-man-1-horse crew and others a 1-man-2-horse crew) and performing the hand labor (some utilizing the available farm help while others had this done on a contract basis).

There was a direct relation between the distance the beets were hauled and the cost per ton for marketing.

The total costs presented in this bulletin are based upon the production of 1,461 acres of sugar beets in the Garland area, 833 acres of beets in the Provo district, and 735 acres of beets in the vicinity of Idaho Falls. The average beet yields for these acreages varied from 13 and a fraction tons at Idaho Falls to approximately 15 tons for the Provo and Garland districts.

Labor costs constituted 54.4 to 58.3 per cent of the total expense of production on the farms visited in this study. This included all man-and-horse labor; also the contract labor. The next largest item was interest on investment in land, which approximated 23.3 per cent of the total costs in the Garland area, 25.5 per cent at Provo, and 21.1 per cent at Idaho Falls.

The total cost of production per acre was $69.03, or $4.65 per ton, for the Garland growers; $69.59 per acre, or $4.65 per ton, for Provo; and $62.68 per acre, or $4.60 per ton, for Idaho Falls.

The total credits per acre were $74.40 at Garland, $74.20 at Provo, and $69.46 at Idaho Falls, thus giving a profit of $5.37, $4.61, and $6.78 per acre for the respective areas. The estimated value of the beet tops was included in these credits.

In the Garland and Provo areas sugar-beet production proved to be the most important enterprise of the farms that were visited. Over 40 per cent of the total farm receipts were secured from the sale of sugar beets. At Idaho Falls sugar beets and potatoes were of about equal importance.

The facts brought out in this study indicate that yield per acre is an essential factor in reducing the cost per ton and consequently in increasing profits. Any change in the system of farm management that will contribute to increased yield without materially increasing the cost of production should receive the consideration of the grower.

A study of the returns on these farms emphasizes the fact that a large number of operators did not have a margin of profit after allowance had been made for all expenses connected with the production of this crop, including interest on investment.

OBJECT.

This investigation was undertaken for the purpose of making a study of the methods of farm practice which have been adopted in a few of the more important areas where the sugar beet has come to occupy a paramount place in the cropping system. Some preliminary observations were made in these areas during the years 1910 and 1911. The work at that time was confined entirely to farm-practice studies. Cultural information was sought with a view to offering suggestions for a few districts where the beet growers were experiencing difficulty in producing satisfactory yields. Subsequently it was felt that information of this character would be of value in planning agronomic experiments that would have a direct bearing upon some of the more urgent problems engaging the attention of the beet grower. The field practice of one district has features which can be adopted with profit in another, and if enough farms are studied many general questions with reference to soil and crop management can be answered. This project was organized not only for the acquirement of information relating to the production of sugar beets, but it was also developed in such a way as to provide growers with an adequate statement concerning the labor requirements of the crop. With these data available, a fair average cost of producing sugar beets in these three districts has been determined.

In working out the cost figures, the man labor was calculated by using an average rate per hour, the latter being based upon the actual wages paid in 1914 and 1915. In order to place all records on the same basis, no account has been taken of the compensation for supervision of the farm business. The work of each operator has been charged against the crop as if some person had been hired to do each task. Likewise, the horse-labor cost was computed on the basis of the average price paid by farmers in the respective districts.

Costs reported are applicable to the years 1914 and 1915. In order to bring the various items down to date, the hours of man and horse labor should be multiplied by the prevailing man and horse rates; likewise, necessary changes should be made where increases or decreases have occurred in cost of materials, use of land, or other costs.

PROCEDURE.

The survey method was adopted in procuring the records that supply the data for this discussion. A schedule was prepared to meet the requirements of the investigation, and these blanks were used by well-trained enumerators who visited the grower and obtained careful estimates covering the business of the farm for the preceding year. The operator was also asked to describe the implements that were employed in handling the beet crop. Furthermore, statements were obtained concerning the size of the crew and the normal time required in performing the various operations. The individual record was therefore compiled by setting down answers to a series of questions dealing particularly with the problems of sugar-beet production. Although very few men keep actual records of the daily work on the farm or of the business transactions which are made from time to time, it has been found that an analysis of a suitable number of farm estimates provides material that indicates the trend of affairs in such a group and conclusions which may be drawn therefrom can be regarded as significant.

COOPERATION.

In developing and projecting these studies the Office of Farm Management worked jointly with the Office of Sugar Plant Investigations of the Bureau of Plant Industry. Acknowledgment is due the farmers in these districts who gave willingly of their time in order to furnish careful estimates with reference to their methods of preparing the soil, planting, cultivating, irrigating, and harvesting the sugar beet. These men also gave information relating to the acreage and yield of the crops grown on the individual farms. The crop sales were given, and it was therefore possible to determine the relative importance of the sugar beet in these systems of farming. Each operator also reported the live stock on hand at the beginning and at the end of the farm year, and a statement was made showing the sales of live stock during the year. The relation of animal industry to beet production may be seen in these estimates. In all of these phases the growers cooperated heartily.

AREAS STUDIED.

Three distinct areas were included in this survey (see fig. 1).

In Utah County, near Provo, Utah, 21 reports were taken for 1914, and 37 farm records were obtained in the same area in 1915. Utah County has been an important beet-producing center for several years. The manufacture of sugar had its beginning in this State as early as 1852, but this pioneer venture did not prove successful. It remained for the farmers of Utah County to demonstrate at a later date the value of the sugar beet as a cash crop. The past 30 years have witnessed the development of an exceedingly important industry for farmers living within the Salt Lake Basin and contiguous territory. In Boxelder County 39 records were obtained for 1914, and to these 40 were added for the crop year 1915. The farms which were visited lie adjacent to Garland, Utah; hence, in this discussion, the name of this town is sometimes applied to the district. A beet-sugar factory was built at Garland in 1903. At present Boxelder County leads all other counties in Utah in the number of acres planted to sugar beets.

The third district in this series furnished 36 records. These farms were located in Bingham and Bonneville Counties, near Idaho Falls, Idaho. The observations on this area were confined to the year 1915. The sugar factory at Idaho Falls, Idaho, was constructed in 1903; thus the beginning of the industry in this area corresponds with the initial work in beet production at Garland.

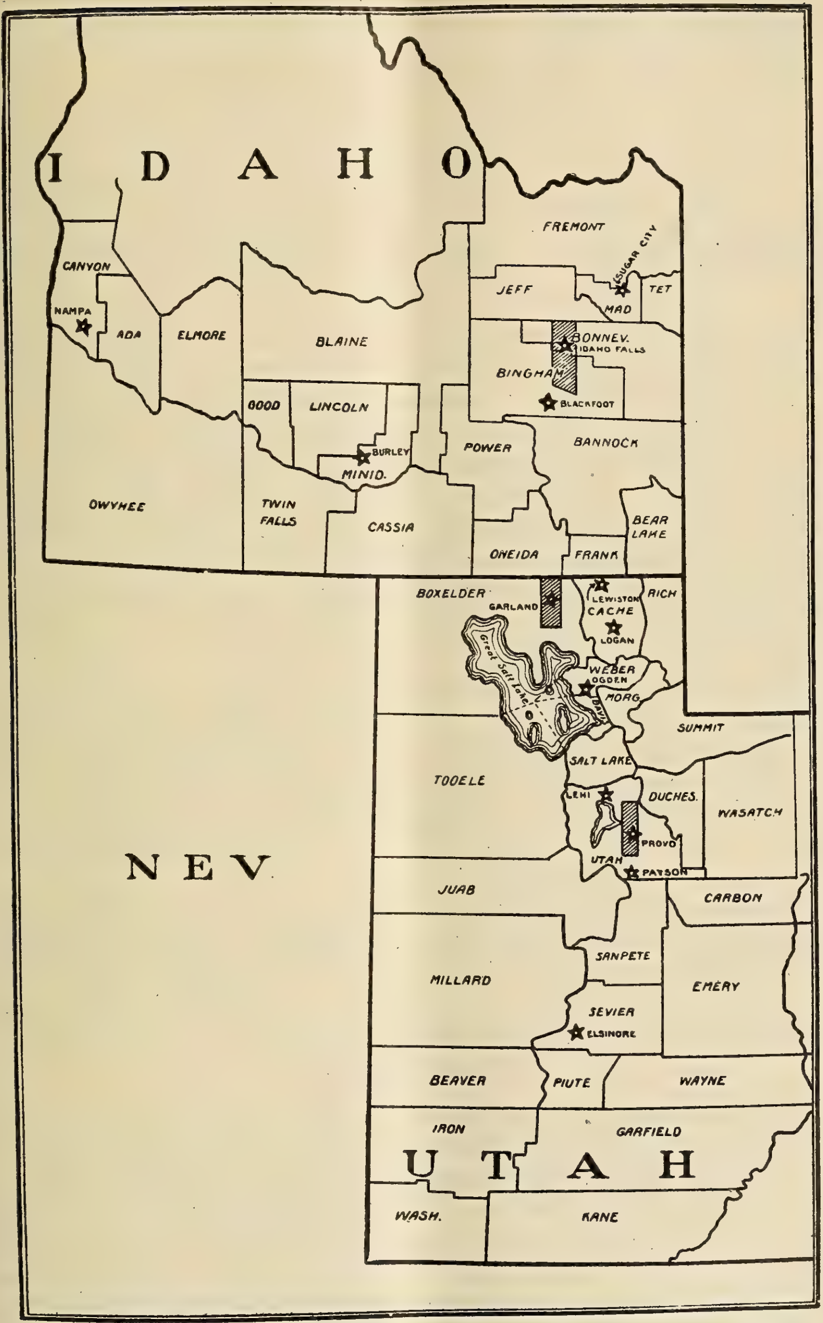

FIG. 1—Shaded areas on map indicate the three districts which were selected for this study. The stars represent the locations of the beet-sugar factories that were in operation during the years 1914 and 1915.

The development of the sugar-beet industry in Utah and Idaho is apparent in Table I.

TABLE I.—*Sugar-beet acreage and yield in Utah and Idaho.*

	Utah.			Idaho.		
	1899	1909	1915	1899	1909	1915
Total acreage	7,546	27,472	59,400	None reported.	15,601	35,900
Production (tons)	85,914	413,846	691,000	do	179,661	375,000
Average yield per acre (tons)	11.4	15.0	11.6	do	11.5	10.4

The figures for 1899 and 1909 were taken from census reports. The 1915 figures are from the Government estimate on the sugar-beet crop in Utah and Idaho. Between the years 1898 and 1909 the sugar-beet acreage in Utah was increased almost fourfold. Within the six years from 1909 to 1915 the area planted and harvested more than doubled. It will be seen that Idaho farmers did not begin raising beets commercially prior to 1900. The past few years have witnessed a decided increase in the acreage devoted to this crop. The slight fluctuations which are apparent in the average yield per acre for the respective years were undoubtedly due to seasonal conditions.

The acreage devoted to beets in the Garland district doubled within the five years from 1910 to 1915. There were 879 beet growers in this county in 1915, and they planted 10,874 acres to this crop. The average beet acreage per farm for the same season was 12.37. This figure shows a slight increase over the preceding four-year average. The normal yield per acre for this region from 1911 to 1915, inclusive, was 11.53 tons.

There were 5,763 acres planted to sugar beets for the Idaho Falls factory in 1911. This area was increased to 8,076 acres in 1915. The average acreage devoted to beets in this district for the five-year period 1911–1915 was 6,198. Beet growers at Idaho Falls made an average yield of 11.18 tons per acre for the same period.

CLIMATIC FEATURES.

The climate in the region under discussion is semiarid in character. There is a considerable variation in the annual precipitation as recorded by observers at various points in the two States. Garland was not included in the list of weather stations which have kept continuous records through a series of years, hence the rainfall for the Bear River district will have to be judged in part from the reports for Corinne The latter station is located at the southern end of the Bear River Valley The average precipitation for Boxelder and Utah Counties, Utah, and Bingham County, Idaho, for a period of years will be found in Table II.

TABLE II.—*Average rainfall by months for 2 districts in Utah and 1 in Idaho.*[a]

	1870–1909, Corinne, Utah, Boxelder County.	1892–1909, Provo, Utah, Utah County.	1881–1908, Idaho Falls, Idaho, Bingham County.
	Inches.	*Inches.*	*Inches.*
January	1.37	1.47	1.59
February	1.24	1.46	1.32
March	1.42	1.65	2.03
April	1.12	1.28	1.16
May	1.44	1.83	1.62
June	.59	.66	1.41
July	.45	.42	.53
August	.59	.75	.82
September	.67	.81	.63
October	1.02	.91	1.02
November	1.05	1.08	1.08
December	1.55	1.39	1.30
Total	12.51	13.71	14.51

[a] Reported by the Weather Bureau, United States Department of Agriculture.

These records exhibit considerable uniformity in the distribution of rainfall by months. The heaviest precipitation occurs in the winter and spring. By combining the rainfall for the months January to May, inclusive, it will be seen that fully 50 per cent of the yearly precipitation occurs within this period. Under average conditions the summer rainfall is exceedingly light. An increase in the monthly rainfall may be noted in October, and this average gradually rises until the maximum is reached in March. In 1914 and 1915 the precipitation for the Provo district was considerably above normal. Boxelder County had for both seasons slightly more than the average rainfall. At Idaho Falls the precipitation was a little below normal for the year 1914 and more than 1 inch above the normal for 1915.

By comparing the yearly averages for the three districts, given in Table II it will be seen that Boxelder County has the least rainfall, whereas the highest precipitation occurs in the Idaho Falls district. The increases coincide with increases of elevation. While it is true that the rainfall at certain periods is sufficient to moisten the soil thoroughly, and at such times may provide enough water to be of value in crop production, there are many occasions when the precipitation is so distributed that crops are not benefited appreciably. The snow which falls upon the mountains during the winter months affords a supply of water which is made available during the summer months and is utilized for irrigation purposes in the adjacent valleys. For most farms the artificial application of water is essential for successful sugar-beet production.

The growing season extends from the latter part of April to the first or second week in October. The latest dates for spring frosts throughout this period varied from April 19 to May 28. In the autumn there was a variation from September 15 to October 18 in the earliest frost dates for Utah. The season at Idaho Falls is probably somewhat shorter than the period indicated for the lower elevations. The Idaho Falls district not only has a higher elevation than the other two, but this area is also some distance farther north than Utah or Boxelder Counties.

SOILS.

The farms included in this study were located largely on four distinct soil types. Fortunately, the Bureau of Soils had classified considerable areas in the three districts selected for these observations. In so far as these records are concerned, the Jordan loam is the most important soil type in the Provo and Garland sections. This type has been described as loamy in character, having a depth of 3 feet, and being underlaid with a stiff, tenacious clay. It is essentially a heavy soil and requires more than an average amount of work to maintain the proper tilth. It is well suited, however, to the production of sugar beets. A few records were taken on Maricopa gravelly loam below Provo. Likewise a small number came from Malade fine sandy loam south of Garland. At Idaho Falls the Yakima loam is the prevailing type. This soil was built upon gravelly loam or water-worn gravel. It is stated that the Yakima loam is easily tilled, loose in texture, and bakes very little on exposure after irrigation.[1]

SIZE OF FARM IN RELATION TO BEET ACREAGE.

A few of the 1914 estimates were taken on farms producing less than 5 acres of beets. The enterprise records for 1915 were confined almost entirely to farms producing 5 or more acres of beets. It was felt that the man who was growing less than 5 acres of beets would not be prepared to give reliable information on field operations, such as harrowing, rolling, floating, cultivating, etc., because the 2 or 3 acre field does not provide sufficient area to keep the crew employed for any considerable length of time, hence the operator would not have the necessary foundation upon which to build his estimate concerning a day's work. All of the counties represented in this study contain a relatively large number of small farms, many of these units not planting more than 3 or 4 acres to sugar beets. A study of Table III will give the reader some idea as to the size of the farms in the four counties represented in this survey. These figures were taken from the Thirteenth United States Census Report. The table also contains a classification of the farms which were included in this survey.

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[1] This paragraph is based upon work done by U. S. Department of Agriculture, Bureau of Soils: Soil Survey, Provo Area, Utah, 1903; Soil Survey, Bear River Area, Utah, 1904; and Soil Survey, Blackfoot Area, Idaho, 1903.

TABLE III.—*Number of farms of specified sizes in 1910 in Boxelder and Utah Counties, Utah, and Bingham County, Idaho; also number of records secured in these counties, 1914–15.*

Size.	Utah County.		Boxelder County.		Bingham County.		Fremont County.
	Number of farms in 1910.	Records secured in 1914–15.	Number of farms in 1910.	Records secured in 1914–15.	Number of farms in 1910.	Records secured in 1914–15.	Number of farms in 1910.
9 acres and under	318	....	83	....	63	....	53
10 to 49 acres	1,530	20	450	24	472	11	445
50 to 99 acres	500	17	281	29	582	12	594
100 to 174 acres	283	17	303	14	790	12	1,372
175 to 259 acres	98	3	122	5	191	1	236
260 to 499 acres	96	1	161	5	145	....	293
500 to 999 acres	29	....	77	2	38	....	75
1,000 acres and above	19	....	50	....	6	....	23
	....	58	....	79	....	36	....

Utah County especially shows a large number of farms under 9 acres; the second group, 10 to 49, contains more than one-half of the farms in this county. The settlement of some of these districts dates back to 1848–1850, and as the practice at that time favored the smaller units it is not surprising to find a large number of such tracts at present. There is a more uniform distribution throughout the various group sizes in Boxelder County than in Utah County. It should be observed that Boxelder County has a much larger land area than Utah County, and as a large part of this excess is known as dry land, it has made necessary the development of many more farms of the larger sizes. The Idaho districts have been developed within more recent years, and although there is here also a tendency in the direction of the smaller units, farms containing a quarter-section (160 acres) are much more common than in the Provo district.

The small farm frequently is cultivated somewhat more intensively than the large farm. Fruit growing is an important enterprise on these tracts. Some farmers give attention to the production of truck crops. On farms of practically all sizes the supplies for the household are not overlooked. Fresh fruit and vegetables are therefore available for the home table.

RELATION OF BEET ACREAGE TO IRRIGATED AREA.

Sugar beets can be grown profitably in the region of this study only on that part of the farm which can be supplied with water artificially. Therefore it is important to know what proportion of the irrigated land is occupied annually with this intertilled crop.

TABLE IV.—*Average acreage per farm, total tillable, irrigated, and in beets, 1914–15.*

District.	Number of farms.	Acres per farm.	Acres tillable.	Acres irrigated.	Acres in beets.	Per cent of irrigated land in beets.
Provo	58	86.55	48.95	41.20	14.36	34.9
Garland	79	104.71	83.00	44.04	18.49	42.0
Idaho Falls	36	91.08	78.54	78.32	20.40	26.0

Practically all of the tillable area on the farms in the Idaho Falls district was under irrigation. (See Table IV.) About 84 per cent of the tillable area on the farms in the Provo district was under ditch. while the Garland farms showed only 53 per cent. A much higher percentage of the irrigated land was devoted to beets at Garland than in the case of the Idaho Falls and Provo farms.

COMPARISON OF FARM ESTIMATES WITH FACTORY RECORDS.

Each sugar factory keeps a record of the acres planted to sugar beets on each farm. The various tracts are measured by the field man, and the planted as well as the harvested acreage is definitely established. At the end of the growing season the product from each field is carefully weighed, and the grower is provided with a scale record showing the actual tonnage harvested. These figures, compiled by the factory, show not only the yield per acre for each farm, but also the average yield for the total acreage harvested. In a study of this character it is therefore possible to check the grower's estimate on acreage, yield, and receipts for the sugar beet with the actual acreage, yield, and receipts as shown by the factory accounts. The estimates which obviously contained grave mistakes were discarded, and the reliable figures made available for the analytical study were used. (See Table V.)

TABLE V.—*A comparison of growers' estimates with factory record,*[a] *average acreage, yield, and return per acre per farm, 1914–15.*

District.	Number of farms.	Acres in beets.		Yield per acre.		Cash return per acre.	
		Estimated.	Factory.	Estimated.	Factory.	Estimated.	Factory.
Garland	79	18.49	18.31	14.85	14.80	69.82	68.66
Provo	58	14.36	14.70	14.96	13.64	69.40	70.34
Idaho Falls	36	20.40	20.7	13.62	12.02	69.47	61.40

[a] See Department Bulletin No. 529, "The Validity of the Survey Method of Research."

In the Garland district the average estimated acreage per farm was 1.06 acres greater than the factory record. There was not much difference in the average yield for the same area, and the cash returns per acre are not far apart. The Provo district shows a very striking correspondence in the acreage and cash returns, but there is a slight difference in the yield per acre reported by the two methods. The Idaho Falls records indicated some variation in the yield per acre, and this is reflected in the cash return per acre. Fewer estimates were obtained in the Idaho Falls area than in either of the other districts.

METHOD OF PRESENTING DATA.

The subject matter in this bulletin was prepared in two parts. The first section deals with the major and minor operations performed by the Utah-Idaho growers in producing the 1914 and 1915 beet crops. Each operation is treated separately. While the farm practice studies as a whole are applicable to 173 estimates, the different methods which are described are not all followed on all farms. Plowing, cultivating, and harvesting were operations common to all records, but the soil tillage subsequent to plowing varied considerably. This was true not only with such work as harrowing, disking, leveling, and rolling, but it was also noticeable in the management of the hand labor. In presenting the farm-practice data the district was taken as the unit, and the results have been compiled so as to show the average crew, average labor requirements, and average cost per acre for each of the three areas studied.

The second part of this bulletin includes a study of the total cost of production. Here the total cost of man labor and horse labor, the total expense connected with the purchase of materials, and all other costs, are combined for the purpose of showing the actual cost of producing an acre or a ton of sugar beets on the fields which were cultivated by these growers. The different costs are distributed over the entire beet acreage for these farms. The practice sheets show the actual acreage covered, and the labor requirements as well as the acre charge are worked out on this basis. When the cost for each of these items is charged against the entire beet crop, a lower figure is shown. As a matter of fact, the entire crop must bear any expense that may apply to a part of the acreage.

CROP ROTATION.

The question of rotating the farm crops has been given some attention in the Provo, Garland, and Idaho Falls districts. While it is true that there are some farms in each area where individual crops are grown continuously upon the same land, the value of systematic cropping has been recognized in each district, and several fairly definite plans may be found in actual practice. Some men are limited by the number of crops which may be grown under their individual conditions, consequently they do not have an opportunity to give the land a change at frequent intervals. Some farms contain dry land as well as irrigated land; the dry land is almost of necessity devoted to the production of grain exclusively, whereas the irrigated land is set aside for alfalfa, sugar beets, and truck or garden crops. It will be seen that this arrangement makes it impossible for some of these men to use grain at regular periods in rotation with sugar beets. Each crop has its adaptations, and these characteristics must be taken into account in planning the work of the farm. With this situation facing the grower, there is a natural tendency to allow sugar beets to follow beets upon the same field for several years; likewise, the hay crop is not disturbed for a comparatively long period.

Alfalfa is regarded as an essential crop in all of the rotations which were suggested. It is usually seeded along with grain, although occasionally it may be started without a nurse crop. After a stand has been obtained, the field is cropped annually for periods ranging from three to eight years. It is quite a common practice to leave the alfalfa for four to five years. Three to four cuttings are made per season, and the yields vary from 3 to 5 tons per acre each year. Generally speaking, the greater part of the hay is fed upon the farm. In the Provo and Garland districts the alfalfa weevil has damaged the crop seriously in recent years. This insect appears to work extensively upon the first crop, and if its activity is not checked the second crop may be shortened materially. When much damage is suspected, cultivation is recommended. This treatment has proven to be effective in averting a loss which would otherwise occur.[1]

The Provo estimates indicate that alfalfa is grown upon the same piece of land for about five years. After breaking, grain was sown the first year on approximately 50 per cent of the farms which were visited. In a few cases grain was used for two years after plowing up the alfalfa. The sugar beet sometimes follows alfalfa, though this is not considered good management, because the alfalfa roots interfere to quite an extent with the early cultivation of the young beets. The use of grain immediately after plowing up the alfalfa gives the grower a chance to subdue the latter crop in part, and the soil can be tilled the subsequent season without pulling out or damaging the sugar beets. The potato was reported in four rotations, following grain in three cases, and coming after sugar beets on the fourth farm. However, the potato does not figure here as an important crop, doubtless because potato diseases have damaged the crop appreciably within the last two or three years. The rule seems to be to plant beets after a crop of grain, which means the second year after breaking, then beet culture is continued for five years or more on the same ground. On a few farms the beet has been grown continuously for periods of 10, 12, and even as high as 18 years.

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[1] Farmers' Bulletin 741, "Alfalfa Weevil and Methods of Controlling It."

About one-third of the men who were consulted in this area stated that a definite cropping system had not been adopted as yet, but these operators were prepared to give suggestions with reference to the length of time alfalfa is allowed to remain down. Continuous beet culture appeared to be the practice on this group of farms.

There is quite a marked similarity between the methods of cropping that prevail in the Provo and the Garland district. On the farms of the latter area the average period through which the alfalfa sod remains unbroken is about five years. Planting grain for one or two years after plowing up the hay crop provides the connecting link between the alfalfa and the sugar beet. The potato enters into the general plan on relatively few farms. The sugar beet is the chief money crop, and naturally occupies a conspicuous place in the rotation. Fully one-half of the growers in this area reported that sugar beets had been grown for five years or more on the same part of the farm. This practice is no doubt due in part to the prevailing opinion that beet land improves from year to year. Many growers contend that they are getting better yields now in fields which have produced eight crops or more than they were able to obtain during the first two or three years of their experience. There is a tendency to overlook the changes which have been made in the methods of culture. The increased yields, if there is such an increase, are undoubtedly due to greater efficiency in producing the crop. It is not unusual to find beets following beets upon the same field 8 to 12 years without the introduction of any other crop. Such a system invites trouble and consequent shortage in yield through the development of plant diseases or the multiplication of insect pests. A few have recognized the serious possibilities of such a situation and are endeavoring to modify this well-established practice. About 33 per cent of the Garland records show that a definite crop rotation has not been fully established. When apple and other orchards are being developed, it is a common practice to grow sugar beets on this land.

There are portions of the Idaho Falls area where the potato is the only cultivated crop and practically no attention is given to the production of sugar beets. For these farms a slightly different rotation has been evolved. The Idaho Falls rotation, which includes alfalfa, potatoes, beets, and grain, is in conformity with the Utah method of cropping. However, under average conditions alfalfa is broken out at the end of the fourth year and potatoes take the place of grain on the newly turned soil. A few operators put in grain immediately after breaking. Potatoes are planted the succeeding year. Beets follow beets for two or three years, after which grain is sown and alfalfa is established once more. Occasionally potatoes are planted for two or three years consecutively after breaking, and beets come the fourth and fifth years. This practice did not appear to be very common. A few men have used the sugar beet on the same field for 7 to 10 years without introducing any other crop.

The following may be cited as typical rotations for the areas surveyed:

Provo and Garland areas:
- Alfalfa, 5 years.
- Grain, 1 year.
- Beets, 5 years or more.
- Grain, 1 year.
  - Reseed to alfalfa.

Idaho Falls area:
- Alfalfa, 4 years.
- Potatoes, 1 year.
- Beets, 2 and 3 years or more.
- Grain, 1 year.
  - Reseed to alfalfa.

VALUE OF MAN LABOR AND HORSE LABOR.

Each farmer furnished an estimate not only of the value of his own labor on the farm, but also of wages paid out for regular and extra labor. In addition, a record was obtained covering the value of horse labor. These rates were tabulated, and the averages derived were as follows:

Man rates and horse rates per hour.

	Boxelder area.	Utah area.	Bonneville and Bingham area.
Man	$0.20	$0.19	$0.20
Horse	.09	.10	.10

There is very little difference in the average rates per hour for man labor and horse labor in these three districts. The customary rate for man labor appeared to be 20 cents per hour, or $2 per day, while the usual charge for horse labor was approximately 10 cents per hour, or $1 per day. The seasonal variation for the first two districts in 1914 and 1915 was so small that the rates worked out for the first season were adopted for the second. This applies to two counties in which records were taken for 1914 and again in 1915. The value of both man labor and horse labor fluctuates from year to year, owing to changes in the rates that are paid.

The labor requirements of any crop do not change as readily as the cash rates per hour or day, hence in discussing the various topics included in this paper special attention has been given to the hours of man labor and horse labor required for each operation. Beet growers are quite familiar with the dollar method of presentation; consequently, money values have been assigned in writing this bulletin. The labor requirements of this crop are also given. Thus, if a change is effected in the labor rates, a few simple calculations will enable the reader to obtain the corresponding value showing the cost per acre or per ton.

FARM PRACTICE IN THE PRODUCTION OF SUGAR BEETS AND RELATED COSTS.

SCRAPING THE FIELD.

The preparation of the seed bed for any cultivated crop grown under irrigation frequently demands some special attention in order to insure a uniform and rapid distribution of water when the proper season arrives. An uneven surface interferes with the run of water and prevents a portion of the field from receiving the amount which is required by the crop to produce an average yield. It is the custom in several of these districts to level the cultivated area with a Fresno scraper (fig. 2). Ordinarily a few days are spent during the fall and winter months with a team and a scraper at this particular task. It was decided to consider this as improvement work, and although a small amount of man labor and horse labor is shown on some of these records, no charge for scraping was made against the beet crop. As a matter of fact, this expense should be distributed through a series of years, and this process, if followed, would render the cost for a single crop season practically negligible. It may be stated that the analysis shows a variation in cost from $1.55 to $2 per acre for scraping. Such work merely adds to the farm capital, and any cost incident thereto can eventually be applied to the various enterprises of the farm as interest charge.

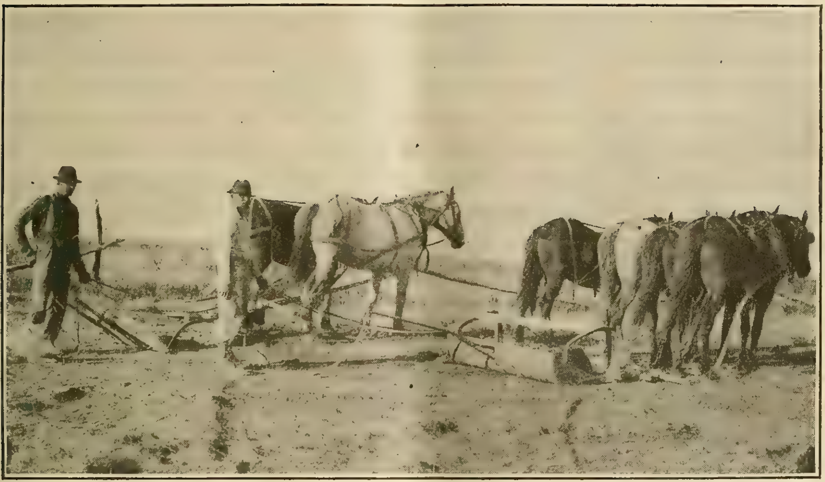

FIG. 2.—Typical crews employed in scraping the field preparatory to plowing. This is done for the purpose of making the surface level for irrigation. In this study scraping was considered as improvement work.

MANURIAL PRACTICE.

Farm manure is regarded as an important by-product of the farm in the beet districts of Utah and Idaho. Of the men who were interviewed, 93.6 per cent had applied manure to the land the preceding season and gave estimates of the value of the manure in the yards as well as of the total time required to haul this by-product to the field. (See Table VI.) It is the general practice to utilize practically all of the manure available on the farm, and occasionally the operator supplements the home supply by hauling from a near-by feed yard or livery barn. Our records show that from one-third to one-half of the beet land was treated with an annual application of farm manure. Without exception the sugar beet gave evidence of direct benefit from the application of manure. In most cases the manure was hauled from the yard to the field in wagons and scattered by hand. In the Provo group the manure spreader was used by 41 per cent of the operators. The hauling was done almost entirely during the winter and early spring months. There is no other work to engage the attention of the farmer at this season of the year, which may explain the common practice of hauling with a wagon. He has plenty of time in which to complete the task, and an investment in a manure spreader has seemed to be unnecessary. To the same reason may be attributed the relatively small crew assigned to this task. On a majority of the farms this operation was done by one man with two horses and a wagon. Where the spreader takes the place of the wagon three horses are usually employed, and frequently an extra man assists with the loading.

Farm manure was sometimes applied to the potato land. Sugar beets were then grown the following year. The claim is made that manure often contains a large number of weed seeds, which germinate and interfere to a considerable extent with beet culture. If manure is scattered on potato land, the noxious weeds appear largely the first season and can be eradicated much more readily.

TABLE VI.—*Manurial practice.*

District.	Year.	Number of farm records.	Acres manured per farm.	Tons applied per acre.	Average crew.		Hours per acre.		Labor cost per acre.
					Man.	Horse.	Man.	Horse.	
Garland	1914–15	74	6.9	20.2	1.4	2.48	21.5	39.7	$7.87
Provo	1914–15	54	7.9	17.2	1.4	2.59	21.5	38.8	7.96
Idaho Falls	1915	34	10.0	15.5	1.6	2.48	19.2	34.5	7.29

The Garland farmers applied manure to approximately one-third of the beet land, the Provo operators slightly more than one-third, and the Idaho Falls growers slightly less than one-half. The application of manure varied from 15.5 tons per acre in the Idaho Falls region to 20.2 tons per acre for the Garland farms. Provo growers applied an amount intermediate between these two averages. The original estimates were procured upon the basis of the number of loads applied per acre, and the operator was then asked to give the weight of an average load as nearly as this could be ascertained. The tons applied per acre were determined from these two figures.

There was practically no difference between the Garland and the Provo group in the labor requirements for this operation. However, as has been pointed out, the rate of application varied. Viewing the problem from the latter standpoint, it may be stated that the Garland operators applied manure at a cost of 39 cents per ton, whereas the costs for Provo and Idaho Falls growers averaged 46 and 47 cents per ton for the respective areas. There was a comparatively high labor cost for hauling and distributing manure in the Provo district during the year 1915. This was shown in the average for 34 farm estimates, and it undoubtedly had some influence on the final result, which includes the findings for two seasons. It may be explained that several of the operators in this area were located some distance from the beet field, and considerable time was consumed in moving the manure from the corral to the farm. The location of the beet field with reference to the farmstead was unquestionably one of the factors that had an important bearing upon costs. It was more difficult to get the relationship of other factors, such as the size of the crew and the method of distribution.

PLOWING.

The sugar beet requires a deep mellow soil. To provide this condition it is necessary to stir the surface to a depth of 8 or 9 inches. On the average farm the land was given only one plowing, though two plowings are sometimes necessary. Plowing was repeated on a few farms in order to bring rough or uneven land into suitable condition for planting. In a few cases two plowings were essential in the preparation of alfalfa land for beets. Twelve operators in the Garland group crowned and subsequently replowed alfalfa land for beets. Crowning means breaking to a depth of 3 inches, which is just deep enough to cut the crowns of the alfalfa plants. It will be seen that crowning was a minor operation in this study. Sometimes the field was disked or harrowed immediately after breaking. When the alfalfa crowns had dried out completely, the soil was turned a second time, the plow being run at a depth of 8 to 10 inches. The crowning was done exclusively in the fall of the year. This operation was performed mainly with a crew of one man and three horses, and the ground was plowed at the rate of 1.7 acres per day. The cost was $2.75 per acre for crowning alfalfa.

Plowing is an essential step in the preparation of a first-class seed bed for beets. Occasionally some of the fields of the farm may be left in such condition that it is not necessary to plow in the spring, but as a rule this operation is performed by all growers either in the autumn or at the beginning of the next crop year. In this investigation two farmers located at Idaho Falls prepared the land and planted beet seed without plowing. These were exceptions to the general practice. A summary of the plowing practice for the remaining farms will be found in Table VII.

TABLE VII.—*Plowing practice.*

District.	Year.	Number of farm records.	Acres plowed per farm.	Average crew.		Hours per acre.		Cost per acre.
				Man.	Horse.	Man.	Horse.	
Garland	1914-15	79	18.1	1	3.3	5	16.3	$2.47
Provo	1914-15	58	14.3	1	3.2	6	18.9	3.03
Idaho Falls	1915	35	19.62	1	3.5	4.4	14.6	2.34

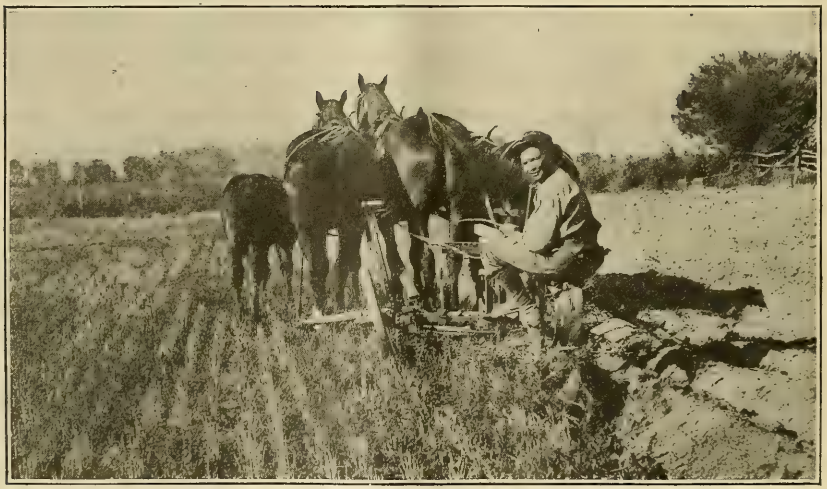

FIG. 3.—Fall plowing stubble land in Utah County, Utah. For the Provo and Garland districts this operation was performed mainly in the autumn.

The 1-furrow sulky plow with a 14-inch bottom appeared in 108 farm reports, thus indicating that this type was used very generally in these districts. Forty-one records included the 2-way plow, while 21 reports show that the soil was turned with an ordinary walking plow. A minor part of the plowing was done with two, three, and four furrow gangs. The dominant crew consisted of one man and three horses. This combination was in evidence on 121 farms. In contrast with the average figures in the foregoing table, this crew did the plowing at a cost of $2.38 per acre at Garland, $2.86 per acre at Provo, and $2.19 at Idaho Falls. The horsepower was increased to

4 in the case of 38 records. Only a few operators plowed with a 2-horse team. Idaho Falls growers plowed the beet land at the rate of 2.25 acres per day, the Garland operators averaged 2 acres per day, while in the Provo area 1.65 acres constituted a day's work. The fact that the soil is fairly heavy may have been responsible for somewhat slower work in the latter instance. The depth of plowing in the three districts varied from 8 to 10 inches.

At Garland and Provo the plowing was done mainly in the fall (fig. 3), whereas in the Idaho Falls district this work was done almost entirely in the spring. The plowing practice in the latter district especially with reference to the time of doing the work may be controlled in part by the combined potato and sugar-beet harvesting operations. Then, too, it may be observed that the Yakima loam is not a heavy type, consequently frost action is not essential in order to obtain a mellow condition. The majority of the beet growers harrowed daily all of the land newly plowed that day; in fact, many made a practice of harrowing up to the plow each half day. Under arid conditions this plan prevents undue evaporation of moisture; it also leaves the surface of the field in much better tilth, and subsequent culture can be carried out much more effectively than when the land is allowed to dry out before harrowing.

DISKING.

In the preparation of beet land the disk harrow was used on relatively few farms. The Garland group contained only 1 disk-harrow record for the year 1914 and 13 records the succeeding season. Apparently the climate conditions were less favorable in 1915 than 1914, hence more work was required to bring the soil to the proper degree of fineness, the disk harrow being selected for the extra work.

TABLE VIII.—*Disking practice.*

District.	Year.	Number of farm records.	Acres disked per farm.	Number of times disked.	Average crew.		Hours per acre.		Cost per acre.
					Man.	Horse.	Man.	Horse.	
Garland	1914–15	14	11.86	2.93	1	3.93	2.08	8.24	$1.16
Provo	1914–15	12	12.33	2.08	1	3.25	2.24	7.33	1.16
Idaho Falls	1915	8	17.81	1.12	1	3.88	1.74	6.76	1.03
Provo, lap one-half	1915	11	13.63	1.50	1	3.36	2.93	9.72	1.53

The disking was done mainly in March and April, Thirteen out of 14 Garland growers and seven out of eight at Idaho Falls reported crews of one man and four horses, while only 8 out of 23 in the Provo district used this crew. Provo also had 14 estimates which reported crews consisting of one man and three horses. It will be observed that the records at Provo were divided into two groups. On 11 of these farms it was the practice to lap one-half in doing the disking.

It was in this group that the maximum cost per acre occurred. Under the foregoing conditions the area covered per day with the disk varied from 5 acres in the Provo district to 14 acres in the Garland section.

Occasionally it is necessary to give special cultivation in the preparation of the seed bed. This is true where the soil happens to be in poor physical condition, or infested with weeds. (See fig. 4.)

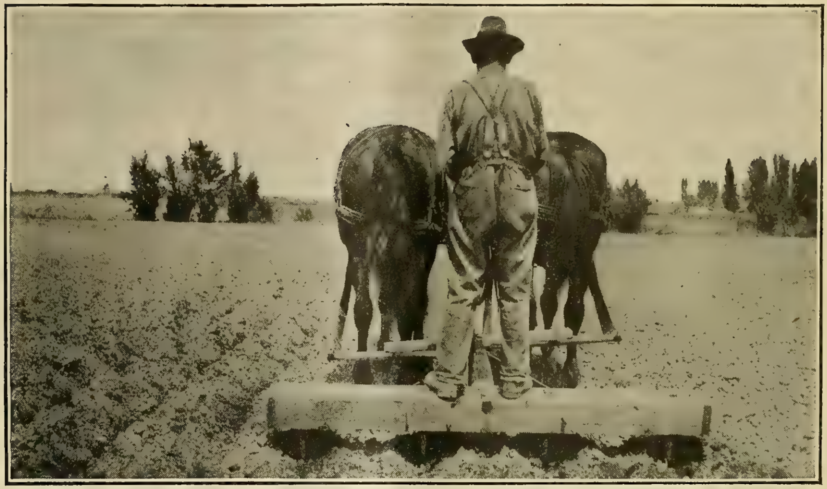

FIG. 4.—Special summer cultivation on land infested with wild oats.

LEVELING.

The leveler is almost indispensable on an irrigated farm. It is usually a homemade affair, and the original cost should not exceed the actual cash outlay for the timber which is used in its construction. It is built by placing two long planks on edge in a parallel position 7 to 8 feet apart; cross pieces similar in width and thickness are set between these two pieces, being adjusted to the proper angle. The entire framework is fastened together securely. This device is drawn over the plowed ground, usually by four horses. Although the primary object is to bring the surface to an even grade, more is accomplished than merely leveling the plowed soil. The leveler serves to break or crush many small clods, and in this way assists in pulverizing the surface. In the order of operations, leveling occupied an intermediate place between plowing and planting.

TABLE IX.—*Leveling practice.*

District.	Year.	Number of farm records.	Acres leveled per farm.	Times leveled.	Average crew.		Hours per acre.		Total cost per acre.
					Man.	Horse.	Man.	Horse.	
Garland	1914-15	80	18.27	1.52	1	3.70	1.42	5.18	$0.75
Provo	1914-15	57	14.37	1.39	1	3.09	1.87	5.60	.92
Idaho Falls	1915	35	20.27	1.58	1	3.66	1.28	4.77	.74

Leveling requires a generous supply of horsepower in order to do the work efficiently. In performing this operation the dominant crew used on the farms studied consisted of one man and four horses. Ninety-three reports gave crews of this size, and the distribution shows that 57 records belonged to Garland, 14 to Provo, and 22 to Idaho Falls. The crew next in size, one man and three horses, was found in 23 Garland, 34 Provo, and 13 Idaho Falls records. Provo farmers gave nine estimates showing crews with one man and two horses. The latter district had the highest cost per acre for leveling. An average day's work with the leveler varied from 7 to 11 acres.

FLOATING.

The float is designed primarily to crush clods. It is homemade and may be placed in the same class as the leveler. It is constructed out of planks lapped one upon another, forming a beveled surface that comes in contact with the soil. The average float was about 8 feet in width. This homemade affair is often attached to the rear of the harrow, thereby pulverizing and crushing the soil in one operation. Occasionally the same result may be obtained by fastening a single plank behind the harrow. There were only 15 records which dealt with floating; 11 of these were obtained at Provo. A survey of the practice on the Provo farms indicates that the ground was gone over on an average of 1.8 times, with time consumed approximately 1.89 man hours and 4.93 horse hours per acre, and cost 85 cents per acre. At Idaho Falls the floating was done only once, at an average cost of 55 cents per acre. One special clod masher was recorded in these studies, the cost with this implement being approximately 39 cents per acre for one treatment.

HARROWING.

The harrow is an important tillage implement on every farm. It is not only used extensively in the preparation of land which is to be seeded to grain, but it also plays a very important part in the development of a suitable seed for intertilled crops. Two types were found in each section—namely, the common spike-tooth harrow and the spring-tooth harrow. Estimates were secured covering the use of each of these implements. (See Tables X and XI.)

TABLE X.—*Harrowing practice (spike-tooth).*

Distict.	Year.	Number of farm records.	Acres harrowed per farm.	Number of times harrowed.	Average crew.		Hours per acre.		Cost per acre.
					Man.	Horse.	Man.	Horse.	
Garland	1914–15	78	18.8	2.82	1	3.2	2.02	6.39	$0.98
Provo	1914–15	50	14.9	2.57	1	2.7	2.6	5.50	1.04
Idaho Falls	1915	34	19.9	3.40	1	3.1	2.2	6.80	1.12

The harrowing was done during the months of March, April, and May. Under average conditions the land was harrowed approximately three times with implements about 10 feet in width. The typical crew consisted of one man and three horses. This size was given for 95 out of 162 estimates. A crew of one man and four horses was second in importance, appearing in 35 records. There were 31 reports which contained information on the use of 1-man 2-horse crew. Nineteen of these were in the Provo district. In this area about 10 acres were considered a day's work with the spike-tooth harrow. The Garland growers averaged about 14 acres per day, while at Idaho Falls 15 acres was the average area covered in 10 hours. Only a few farmers at Idaho Falls used the spring-tooth—a fact which undoubtedly accounts for the greater use of the spike-tooth in comparison with the Utah districts.

TABLE XI.—*Harrowing practice (spring-tooth).*

District.	Year.	Number of farm records.	Acres harrowed per farm.	Number of times harrowed.	Average crew.		Hours per acre.		Cost per acre.
					Man.	Horse.	Man.	Horse.	
Garland	1914–15	35	17.9	1.60	1	3.48	1.76	6.08	$0.90
Provo	1914–15	29	11.05	1.77	1	2.89	2.50	7.20	1.20
Idaho Falls	1915	7	11.40	1.80	1	3.70	1.74	6.30	.98

Spring-tooth harrowing was reported in 71 farm records, the majority of these being divided about equally between the Garland and Provo districts. Comparing the work done with the spring-tooth with that done with the spike-tooth harrow, it will be observed that the fields were not gone over so frequently with the spring-tooth. The average width of the latter was about 6½ feet. Forty-six records gave a crew of one man and three horses. In the Garland area 18 reports were based upon a 1-man and 3-horse crew, while 17 were applicable to a 1-man and 4-horse crew. Provo farmers covered about 7 acres per day with this type of harrow, while the Garland operators averaged 9 acres.

ROLLING.

At Garland one-half of the rolling was done during the early part of May. A study of the records shows that a part of the rolling preceded planting by a few days, sometimes coming on the same day as the planting. Manifestly the roller was run over the fields at this time for the purpose of creating a smooth, even surface for the drill. In order to get straight rows, the driver must see the trail which has been left by the marker, and this line can be distinguished most readily on a newly rolled field. Under certain conditions, the roller may be operated for the purpose of breaking down a cloddy surface. Such work usually accompanies other tillage operations, such as harrowing and leveling. The roller may be utilized after the seed has germinated and the young plants are pushing through to the surface. This operation is known as "rolling beets." Light showers may cause a crust to form on the surface, and if this be permitted to develop fully the small plants may have difficulty in reaching the light. Under such conditions rolling sometimes breaks the crust and insures a better stand. Rolling before cultivation facilitates the latter operation, and undoubtedly aids in removing small obstructions such as soil lumps that interfere with blocking and thinning. (See Tables XII and XIII.)

TABLE XII.—*Rolling practice.*

District.	Year.	Number of farm records.	Acres rolled per farm.	Hours per acre.		Cost per acre.
				Man.	Horse.	
Garland	1914–15	31	16.8	0.74	1.5	$0.29
Idaho Falls	1915	6	22.8	.62	1.47	.27

Rolling before planting occurred on 37 farms. At Garland the beet land was rolled one and one-third times, and 15 acres were covered daily at a cost of 29 cents per acre. The crew for all farms consisted of one man and two horses.

TABLE XIII.—*The practice of rolling beets.*

District.	Year.	Number of farm records.	Acres rolled per farm.	Hours per acre.		Cost per acre.
				Man.	Horse.	
Garland	1914–15	29	16.8	0.71	1.43	$0.27
Provo	1914–15	18	13.1	.69	1.39	.27
Idaho Falls	1915	12	19.2	.62	1.25	.25

The crews for rolling beets were the same as those used in the preceding practice. A day's work rolling beets varied from 14 to 16 acres. Thirty-four per cent of the farm records included rolling beets as a part of production. Where rolling follows the thinning, the soil is made firm about the young plants, and it is stated by some who are familiar with beet culture that this practice promotes growth.

DITCHING.

A certain amount of ditch cleaning must be done annually on an irrigated farm. This may include work on the lateral which carries water from the main canal to the farm proper, or it may take into account the removal of silt and other débris from the distributing laterals on the farm. Whatever work is done should be divided evenly between those enterprises to which the operation is directly chargeable. The sugar beet should bear a fair proportion of this cost. This cleaning does not require much time, consequently the total charge for any given farm is small. In some cases the operation includes both man labor and horse labor; on other farms the work involves hand labor only. Frequently a plow may be used to advantage in removing the accumulated silt from the bottom of the lateral. A V-shaped machine is sometimes substituted for or used after the plow. The ditching is usually performed a few weeks before it is necessary to make a run of water. In procuring these estimates on ditching practice, only such work as the operator applied directly to the beets was put into the record. The data with reference to ditching were tabulated in two classes, the first including those farms where man labor only was involved, the second embracing the work which required both man labor and horse labor. Some growers did a part of the ditching with man and horse labor and completed the task with hand labor only.

One hundred and forty-five reports contained information relative to the use of man labor only in connection with ditching practice. A few farmers in the Provo and Garland districts cleaned the ditches twice during the season. However, on the majority of these farms the work was done but once. The Garland records showed that 2.07 man hours were expended per acre, involving a cost of 41 cents. The Provo estimates gave 1.86 man-hours per acre with an attendant cost of 35 cents, while Idaho Falls growers devoted 1.01 hours to ditching at a cost of 20 cents per acre.

Eighty-six records reported on ditching practice with both man labor and horse labor. The ditches were cleaned once during the season. The man labor varied from one-third to six-tenths of an hour per acre, and the horse labor ranged from eight-tenths of an hour to 1.19 hours per acre. The Garland estimates reported the maximum time for this operation, while the minimum requirement was given for the Idaho Falls growers. The Provo labor for ditching was slightly higher than that of Idaho Falls. At Garland the cost amounted to 24 cents per acre; at Provo, 17 cents; and Idaho Falls, 16 cents per acre.

COMMERCIAL FERTILIZERS.

These materials are not used extensively in the irrigated districts of the west. Occasionally this item of cost enters into the farm record, but as a rule very few men buy and apply commercial fertilizers in the intermountain country, especially for the improvement of the beet land. The records for 1914–15 did not indicate that any commercial materials had been purchased.

PLANTING.

In the beet-growing districts of Utah it is customary for the factories to own and operate the beet drills. Usually the planting is not done by the individual grower, but by some party employed by the sugar company to do this work on a number of farms within a given area. The men engaged for this purpose usually have small farms and are therefore in a position to do some outside work. There are several advantages in this arrangement. It is very evident that the man who operates a drill for several days in succession can do a better grade of work than the man who plants a 6 or 10 acre tract which requires a fraction of a day or at most not more than a full day per year. Furthermore, the small farmer is not required to carry an investment in a piece of machinery which is used only a few hours each year. A direct charge of 50 cents per acre is made to cover the planting and the rent of the drill. Beet seed is sold to the farmers at the rate of 15 cents per pound, and about 15 pounds per acre are planted. A few growers used slightly less than 15 pounds per acre, while some exceeded the standard quantity. The farmer hauls the seed from the factory or warehouse to the farm. This work is done at a season of the year when the fields do not require attention, or is made a secondary feature of some special trip to town. The item of hauling seed is cared for under the heading "Overhead charges."

The operators who did their own planting gave estimates on this practice, and the results are reported in Table XIV.

TABLE XIV.—*Planting practice.*

District.	Year.	Number of farm records.	Acres. planted per farm.	Hours per acre.		Total cost per acre.
				Man.	Horse.	
Garland	1915	5	22.80	0.74	1.48	$0.28
Provo	1914–15	8	21.38	.89	1.78	.35
Idaho Falls	1915	24	19.50	.92	1.84	.37

The rows are uniformly 20 inches apart. In each district the crews consisted of one man and two horses (fig. 5). It will be noted that the estimates for Garland and Provo were limited to a few farms. Sixty-six per cent of the growers at Idaho Falls reported on planting. The work was done in the same manner as in the other districts. Ten to thirteen acres constituted an average day's work. By comparing the farm rate for planting in these three districts with the contract price, which was 50 cents per acre, it will be seen that the cost was 22, 15, and 13 cents per acre less for the respective areas than the contract price for this work. The difference may be considered as the charge for the use of the drill.

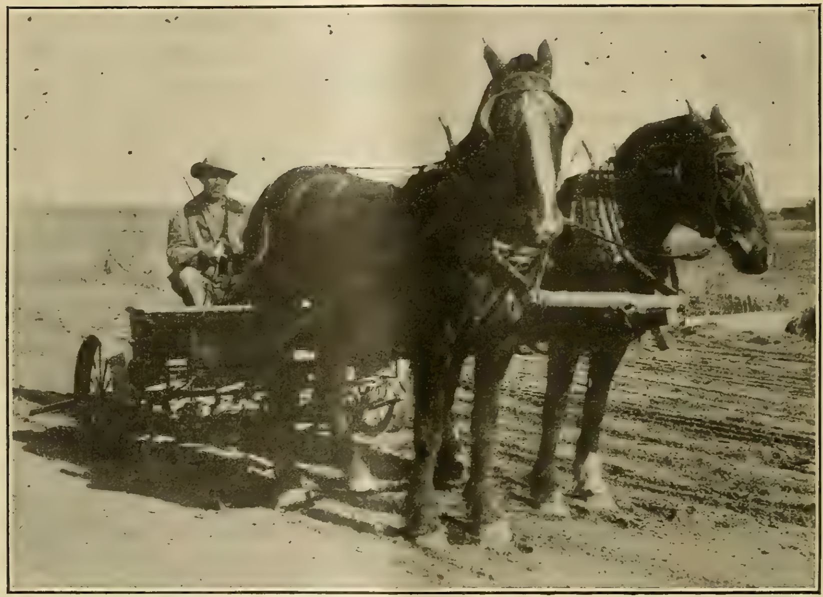

FIG. 5.—Putting in beet seed with a 4-row drill. For this operation the crew consists of one man and two horses.

CULTIVATING.

Intertillage should begin early. The beet crop is cultivated from three to seven times, depending upon soil conditions and area under cultivation. Usually all of the cultivation is completed before irrigation; in a few cases the two operations overlapped. Blocking and thinning proceed simultaneously with cultivation; however, the discussion of hand labor will not be taken up by parts but will be considered as a whole. (See Table XV.)

TABLE XV.—*Cultivating practice.*

District.	Year.	Number of farm records.	Acres cultivated per farm.	Times cultivated.	Average crew.		Hours per acre.		Total cost per acre.
					Man.	Horse.	Man.	Horse.	
Garland	1914–15	73	18.14	3.78	1	1.88	4.24	7.54	$1.53
Provo	1914–15	58	14.36	4.66	1	1.41	6.98	9.20	2.25
Idaho Falls	1915	35	20.30	3.97	1	2.00	3.88	7.40	1.52

Regular beet cultivators were used in these areas. At Garland and Idaho Falls the number of cultivations averaged approximately four. The Provo estimates gave an average of 4.6. Sixty-eight records in the Garland districts indicated the use of a four-row cultivator (fig. 6), which was operated by crews consisting of one man and two horses. Similar crews were reported in connection with 22 Provo estimates, and for 34 farms at Idaho Falls. There were 13 estimates at Garland and 34 at Provo which showed the use of a two-row cultivator, the crews in this case being one man and one horse. The Provo district had the largest number of two-row cultivators. (See Table XVI.)

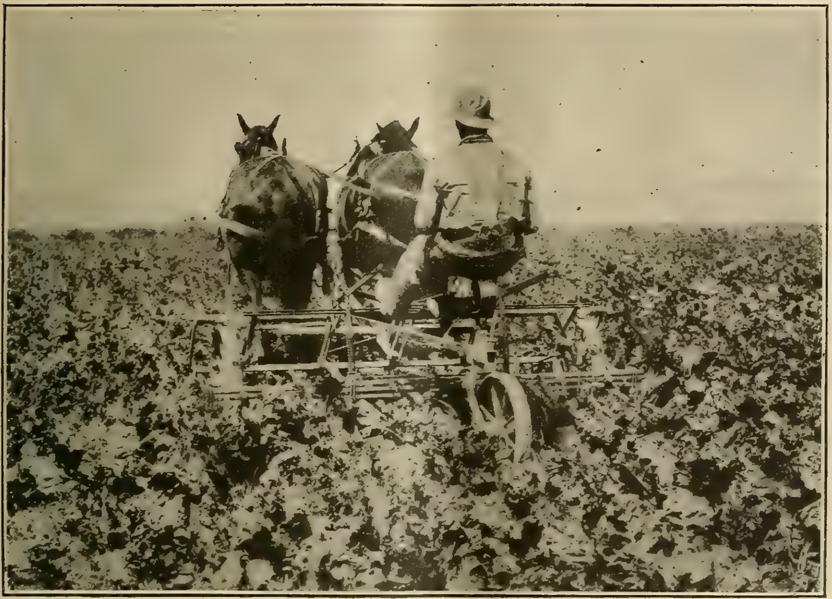

FIG. 6 (A).—Cultivating sugar beets with a crew of one man and two horses. This type tills the soil between four rows.

TABLE XVI.—*Average time and cost of cultivating with 2 and 4 row implements.*

Implement.	Crew.		Number of records.	Per cent of records.	Acres cultivated.	Times cultivated.	Hours per acre.		Total cost per acre.
	Man.	Horse.					Man.	Horse.	
2-row cultivator	1	1	46	27.7	11.29	4.44	7.74	7.74	$2.24
4-row cultivator	1	2	120	72.3	19.07	3.87	4.09	8.18	1.56

The 4-row cultivator, with its crew of one man and two horses, assisted in reducing the number of man hours expended per acre, and this in turn was the factor which lowered the total cost per acre. It may not be advisable to maintain a 4-row cultivator for every farm, but it ought to be possible to own and use such a cultivator cooperatively. The necessary horsepower is available on practically all farms.

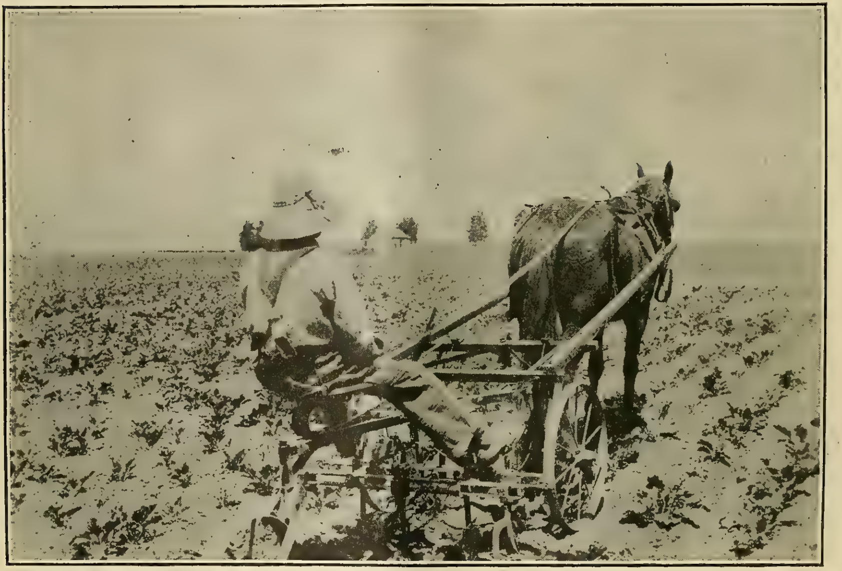

FIG. 6 (B).—Cultivating sugar beets with a crew of one man and one horse.

FURROWING.

Furrowing out is done to open up furrows between the beet rows prior to irrigation. There is a striking correspondence between the furrowing out and the cultivation practice in these three districts. This work is usually performed after the last cultivation. Special attachments which take the place of the regular teeth are provided with each beet cultivator. On many farms it is the custom to run the water between every other row, alternating with each irrigation, and these are the spaces which require special attention at the completion of the last cultivation. There are other cases where the water is run between every row. As a rule it is not necessary to furrow out more than once; however, in these three groups this number was exceeded in some cases. Provo estimates averaged one and one-half times. Naturally the various types of machines represented in cultivation practice appeared again in this work. (See Table XVII.)

TABLE XVII.—*Furrowing practice.*

District.	Year.	Number of farm records.	Acres furrowed per farm.	Average crew.		Hours per acre.		Total cost per acre.
				Men.	Horse.	Man.	Horse.	
Garland	1914–15	73	18.14	1	1.85	1.14	2.05	$0.41
Provo	1914–15	54	14.36	1	1.44	1.82	2.43	.59
Idaho Falls	1915	35	20.3	1	2.00	1.03	1.97	.40

The size of crew and type of implement were undoubtedly the features which determined the greater expenditure of labor and the higher cost for furrowing-out shown in the Provo district.

IRRIGATION.

Irrigation, which is the artificial application of water to the land, requires only man labor. It has been pointed out that the precipitation for Utah is exceedingly light; consequently a crop like the sugar beet can not usually be brought to maturity without resorting to irrigation. Now and then lands may be found which will produce good crops of beets without irrigation, or it may be that the crop is carried to maturity with one irrigation only. Such lands are usually located so that they receive the benefit of seepage water from a near-by canal, or they may obtain the season's supply from an adjacent lake or reservoir. The irrigation season extends from June to September. (See Table XVIII.)

TABLE XVIII.—*Irrigation practice.*

District.	Year.	Number of farm records.	Acres irrigated per farm.	Number of times irrigated.	Man Hours per acre.	Total cost per acre.
Garland	1914–15	73	17.59	3.71	6.89	$1.38
Provo	1914–15	55	14.06	3.89	7.16	1.36
Idaho Falls	1915	36	20.40	4.10	8.40	1.68

The labor requirements for irrigation in the Garland and Provo districts were quite similar, and the total cost per acre was approximately the same. At Idaho Falls slightly more time was spent irrigating each acre of land, resulting in an increased cost of 30 cents per acre. It is possible that the difference in cost may be explained by the fact that the Yakima loam did not retain the water as well as did the Jordan loam, necessitating a large number of applications, and thereby requiring more time per acre to do this work. (See figs. 7 and 8.)

BLOCKING AND THINNING.

Sufficient beet seed is usually drilled in the row to give more plants than are required, provided a good germination is obtained. As soon as the plants are large enough to distinguish the rows, the blocking and thinning are done. The blocking, which means chopping out surplus plants with a hoe, leaves small clusters of beets 10 to 12 inches apart in the row. The thinning, which is done by hand, takes out the surplus plants in each cluster, thereby leaving the proper number of beet plants in the row. On the small farm the operator, with the assistance of other members of the family, does this part of the work. The blocking is done with a hoe which averages about 6 inches in width. The small bunches of beets were left about 10 to 12 inches apart in the row in the Garland and Provo districts. At Idaho Falls the estimated distance was about 14 inches. The laborer has instructions to leave the strongest and most vigorous plants, and these are disturbed as little as possible. When this precaution is not observed it usually takes the young plants a few days to recover from the setback they receive. A perfect stand can be obtained only by exercising care at this stage of the cultivation of the crop.

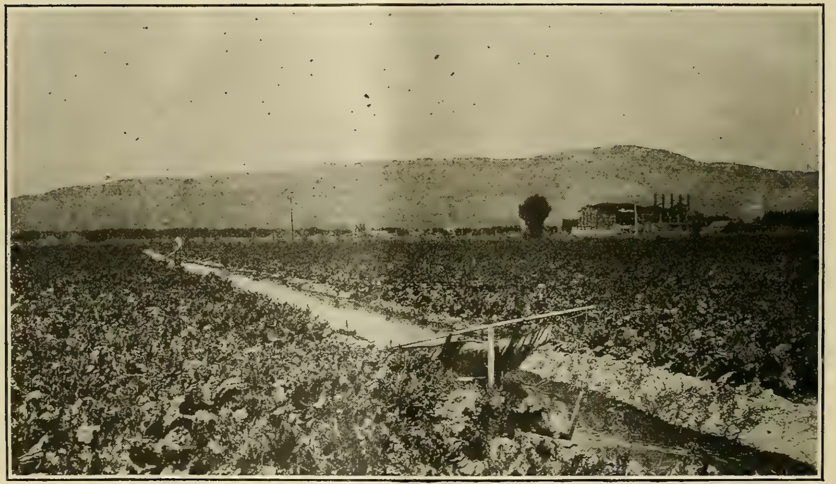

FIG. 7.—Making openings along the field laterals in order to irrigate sugar beets on portion of field to left of large stream of water. A canvas dam may be seen in the foreground.

The handwork with sugar beets may be considered from the standpoint of contract labor covering all the items in question, or it may be discussed from the viewpoint of the farmer who does a part or possibly all of the handwork. The actual cash outlay furnishes a very reliable check on any estimates which may be given by men who make a practice of doing their own handwork. (See Table XIX.)

TABLE XIX.—*Comparative cost of blocking and thinning.*

District.	Year.	Number of farm records.	Acres blocked and thinned per farm.	Hours per acre.	Cost per acre.
Garland	1914-15	32	14.82	21.32	$4.26
Provo	1914-15	13	9.23	23.43	4.45
Idaho Falls	1915	17	11.6	23.72	4.74

The difference in the labor requirements for blocking and thinning in Provo and Idaho Falls districts was exceedingly small. The Garland reports placed this requirement more than two hours per acre less than for the other areas. The customary contract price for this work was $6 per acre at Garland and Idaho Falls and $5 at Provo.

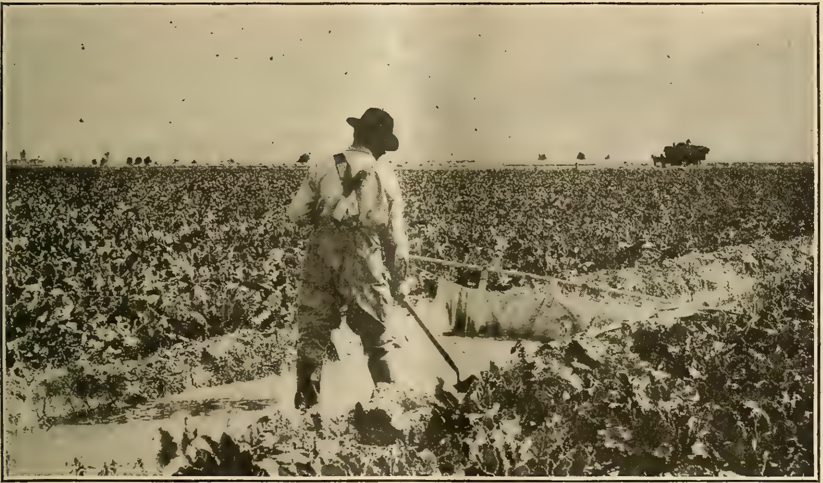

FIG. 8.—Making a new set in a field lateral. A canvas is laid down in the ditch with the free edge toward the approaching stream of water, and soil is thrown upon the canvas for the purpose of holding it in place.

HOEING.

The hoeing is done during the early summer months. Under ordinary conditions the fields are hoed twice. Where a contract is involved, the laborer agrees to keep the field free from weeds. This means hoeing the beets twice, and occasionally some weed pulling is necessary later in the season. In 1915, 77 estimates were secured on the first hoeing, and the average time varied from 9 to 11.5 hours per acre, with costs ranging from $1.79 to $2.18 per acre. There were 74 records for the same season on the second hoeing. The labor for the second hoeing varied from 5.7 to 8.1 hours per acre, involving costs of $1.14 to $1.54 per acre. Eleven growers in the Provo district reported on a third hoeing. The labor in this case amounted to 5.6 hours per acre, with a cost of $1.12 per acre. Weeding was shown on 15 records, 13 of which came from Provo. The cost for this work was 88 cents per acre.

TABLE XX.—*Comparative contract prices for hand labor.*

Kind of work.	District.		
	Garland.	Provo.	Idaho Falls.
Blocking and thinning	$6.00	$5.00	$6.00
First hoeing	2.50	2.50	2.50
Second hoeing	1.50	1.75	1.50
Topping and loading 12 tons	7.80	7.20	10.00
Total	17.80	16.45	20.00

Certain growers made a practice of doing a part of the handwork themselves, the remainder of this labor being done by contract. In the Garland and Provo districts several operators contracted the blocking and thinning, also the pulling and topping, but most of the hoeing was done by the family. The contract prices which were paid in these areas varied considerably. (See Table XX.) The usual price for blocking and thinning at Provo was $5 per acre, while pulling and topping cost 60 cents per ton. At Garland $6 per acre was the customary price for blocking and thinning, and the prevailing rate for pulling and topping was 65 cents per ton. A few growers contracted hand labor on a tonnage basis at $1.65 to $1.90 per ton. On the other hand, a few paid a flat price of $21 per acre for a 12-ton yield, making provision for a bonus of 50 to 75 cents per ton in cases where the yield exceeded the stipulated return. At Idaho Falls the general practice included the payment of $20 per acre for a 12-ton yield, with a bonus of 60 cents per ton for each increment of 1 ton. Where the yield falls below 12 tons per acre, the grower has the privilege of deducting 50 cents for each ton below the yield stated in the agreement.

Frequently the topping is done directly from the row of standing beets, while in other cases the beets are pulled and placed in piles, from which the topping is done. It should be stated that the lifter loosens the beet in the soil so that the roots can be taken out readily by hand. For some districts the topping, especially when placed on a contract basis, included some work loading beets from the field piles. The cost per acre at the usual contract rates is somewhat higher than the average cost given by the growers who did this work themselves. Seventy-seven estimates were obtained on pulling and topping practice, and the results are shown in Table XXI.

TABLE XXI.—*Topping practice.*

District.	Year.	Number of farm records.	Acres topped per farm.	Tons per acre.	Man hours per acre.	Cost per acre.	Cost per ton.
							Cents.
Garland	1914–15	29	15.34	14.74	23.48	$4.70	31.9
Provo	1914–15	37	14.10	14.82	28.61	5.44	36.7
Idaho Falls	1915	11	14.10	10.9	27.92	5.58	51.2

The estimated cost of pulling and topping at Garland was 31.9 cents per ton, as compared with 65 cents per ton on a contract basis. The average estimated cost per ton at Provo was 36.7 cents per ton, the usual contract price paid for the same work being 60 cents. Idaho Falls growers estimates were 51.2 cents per ton, as compared with a contract rate of 83.3 cents, where the yield was 12 tons per acre.

LIFTING.

The harvest season begins late in September and frequently extends well into the month of November. As the harvest season approaches, the field men gather samples of beets from the different fields. Laboratory tests on these beets indicate the sugar content and the coefficient of purity and determine when the beets are ready to pull. The 1-row lifter was used uniformly in these three districts. The lifting is done at the same time as the hauling. On many farms the operator does this work during the early part of the day, enough beets being loosened to keep the toppers busy for the remainder of the day. When not employed at this task the lifting crew hauls beets to the loading station. On the larger farms it is customary to keep one crew busy lifting. (See Table XXII.)

TABLE XXII.—*Lifting practice.*

District.	Year.	Number of farm records.	Acres lifted per farm.	Average crew.		Hours per acre.		Total cost per acre.
				Man.	Horse.	Man.	Horse.	
Garland	1914–15	69	17.99	1	3.04	4.71	14.31	$2.23
Provo	1914–15	56	14.52	1	2.48	5.98	14.69	2.61
Idaho Falls	1915	35	19.20	1	2.90	4.66	13.48	2.28

In the Garland district there were 58 reports, based upon crews containing 1 man and 3 horses. Idaho Falls growers on 32 farms used similar crews. At Provo the estimates were about equally divided between 1-man and 2-horse and 1-man and 3-horse crews, there being 29 of the former and 27 of the latter. The cost per acre was 37 cents greater at Provo than at Garland. For these districts a day's work varied from 1.67 to slightly more than 2 acres.

HAULING.

The hauling season coincides with the harvesting season. When the latter begins late in September or early in October, the greater part of this work will be completed by the end of November. The sugar beet is a bulky and heavy product to handle, hence good wagons with substantial racks are an important part of the grower's equipment. Ample horsepower must also be provided to haul the beets from the field to the dump, slicing station, or factory. Formerly many of the sugar beets were unloaded by hand, but under present conditions this work is done mechanically. When the soil is soft an extra team may be required in the field for the purpose of assisting the regular crew to haul the loads to a solid roadbed. (See Table XXIII.)

TABLE XXIII.—*Hauling practice.*

District.	Year.	Number of farm records.	Tons per acre.	Average crew.		Hours per acre.		Total cost per acre.	Cost per ton.
				Man.	Horse.	Man.	Horse.		
									Cents.
Garland	1914–15	75	14.60	1	3.50	11.96	42.61	$6.22	42.6
Provo	1914–15	58	15.10	1	2.93	14.35	40.20	6.75	44.9
Idaho Falls	1915	30	13.50	1	3.67	8.71	31.87	4.93	36.5

One hundred and sixty-three farm reports were secured on hauling practice. A few growers hired the beets hauled. The price for hauling on contract varied from 35 cents to 75 cents per ton. The customary price appeared to be 50 cents per ton for a haul of one and one-half miles. In the accompanying record this rate varied from 36.5 cents per ton for the Idaho Falls group to 44.9 cents per ton for the Provo group. Forty-three farm reports in the Garland area indicated the use of one man and four horses in this operation. Practically all of the remaining Garland records were applicable to a 1-man and 3-horse crew. The Provo reports included 19 crews with one man and four horses, 16 with one man and three horses, and 23 with one man and two horses. At Idaho Falls the usual crew consisted of one man and four horses.

The distance between the beet fields and the loading station naturally has an influence on the cost of delivery. It will be seen that in marketing a crop like sugar beets, where the yield from 1 acre weighs 12 to 15 tons, the product of a single acre will require several trips with one wagon; and if there is a long haul ahead of the operator the cost of handling the crop will be much greater than it is on the farm which has a loading station nearby. This relationship is shown in Table XXIV.

Table XXIV.—*Relation of distance from loading station to cost of delivering the sugar beet.*

Group.	Distance.	Average distance.	Number of farm records.	Average crew.		Average cost per ton.
				Man.	Horse.	
	Miles.	*Miles.*				
1	1½ or less	0.93	79	1	3.22	$0.370
2	1½ to 3	2.31	62	1	3.31	.446
3	3 to 4½	3.93	19	1	3.78	.550
4	Over 4½	5.30	3	1	4.00	.610

Practically all of the men who gave estimates on hauling are classified in the first three groups. By comparing group 1 with group 3, it will be seen that the cost per ton was 18 cents greater in the latter than in the former. With a yield of 15 tons per acre, this would mean a cost of $2.70 per acre above that of the minimum average haul.

COST OF PRODUCING SUGAR BEETS.

The cost figures in this summary are classified under three headings, viz, (1) labor, (2) materials, and (3) other costs. This compilation covers the total number of acres harvested. These data are therefore applicable to the total beet acreage as reported in 79 Garland, 58 Provo, and 36 Idaho Falls records. The Garland estimates included a total of 1,461 acres of beets. Provo had 833 acres, and Idaho Falls 735 acres. The total cost for each district was calculated for these acreages. Dividing the total sum of all costs in each district by the number of acres grown therein gave the cost per acre for each section. The cost of producing a ton of sugar beets in the respective areas was determined by dividing the total of all costs by the total number of tons marketed. A weighted average is therefore represented in the final result.

LABOR COSTS.

Labor comprises operator's labor, horse labor, and contract labor. By adding these together the total labor cost for each district was obtained. (See Table XXV.)

Table XXV.—*Labor costs.*

District.	Year.	Number of farm records.	Total acres in beets.	Cost per acre.	Cost per ton.
Garland	1914–15	79	1,461	$40.18	$2.71
Provo	1914–15	58	833	38.08	2.54
Idaho Falls	1915	36	735	35.29	2.59

The labor cost for the Idaho Falls area was approximately $5 per acre less than the amount reported in the Garland estimates. When reduced to the average cost per ton, the lowest figure was shown for the Provo group—namely, $2.54 per ton. It will be recalled that the contract rate which prevailed at Idaho Falls was $20 per acre. This is 57 per cent of the total labor cost.

COST OF MATERIALS.

Cost of materials includes the value of the manure in the yard, money spent for the purchase of manure on a few farms, expenditures for beet seed, and water assessments. (See Table XXVI.)

TABLE XXVI.—*Cost of materials.*

District.	Year.	Number of farm records.	Total acres in beets.	Cost per acre.				Cost per ton.
				Manure.	Seed.	Water.	Total.	
Garland	1914–15	79	1,461	$3.62	$2.21	$0.93	$6.76	$0.45
Provo	1914–15	58	833	4.22	2.24	.49	6.95	.46
Idaho Falls	1915	36	735	3.52	2.18	1.47	7.17	.53

Manure.—Each grower gave an estimate of the value of manure used, thus furnishing a basis for computing the manure charge. There was a slight difference in the rate of application for the respective districts. The Idaho Falls group shows the lowest rate of application per acre and the lowest charge. The Garland group shows the highest average application of manure, but the highest manure charge is for the Provo area. It should be observed, however, that the total manure charge was distributed over a relatively large acreage in the Garland district. The area manured per farm was also less than in the Provo district.

Seed.—The common practice in these areas was to plant beet seed at the rate of 15 pounds per acre. The seed was sold to the grower at 15 cents per pound, making a total charge of $2.25 per acre. A few farmers in the groups studied used less than 15 pounds of seed per acre, the average cost varying from $2.18 to $2.24 per acre. These rates are a fraction below the standard charge.

Water.—The farms in the Garland area invariably showed a uniform charge of $1 per acre for water assessments. This group, however, contained some rented farms. In such cases the water assessments were not paid by the operator, but were included in the rent. With these farms eliminated, the average rate is lower than $1 per acre. In the Provo district a number of growers obtained their irrigation water from artesian wells. This feature had a tendency to reduce the number of men who paid water assessments on a given ditch, and the rate per acre is consequently comparatively low for this area. The average water assessments reported for the Idaho Falls district was 98 cents per acre higher than that for the Provo district.

The Garland rate was intermediate between those for the other areas. Taking all such expenses into account, it will be seen that there is very little difference in the three districts.

OTHER COSTS.

"Other costs" are charges which apply to the farm as a whole. They must therefore be distributed so that each enterprise will carry its proper proportion of the general expenses. Such items as insurance, taxes, interest on land, land rent, machinery charges, and miscellaneous expense constitute this list. (See Table XXVII.)

TABLE XXVII.—*Other costs.*

District.	Year.	Number of farm records.	Total acres in beets.	Cost per acre.					Cost per ton.
				Insurance and taxes.	Interest and rent.	Machinery.	Miscellaneous expense.	Total.	
Garland	1914–15	79	1,461	$1.16	$16.09	$3.41	$1.43	$22.09	$1.49
Provo	1914–15	58	833	1.95	17.77	3.49	1.35	24.56	1.65
Idaho Falls	1915	36	735	1.67	13.28	4.00	1.27	20.22	1.48

Insurance and taxes.—Figures covering farm insurance and taxes, and an estimate of the total real-estate investment and the value of the beet land per acre, were obtained from each operator. From these data the investment in beet land was computed, and from this the percentage the beet-land investment is of the total real-estate investment. Then, by taking this percentage of the total farm insurance and taxes, the charge against sugar beets was readily ascertained. This method was employed where the operator was the owner of the land. Where the operator was a renter, the insurance and taxes were usually small. The operators in the respective districts were mostly owners. The insurance and taxes varied from $1.16 per acre in the Garland area to $1.95 per acre in the Provo section.

Interest and rent.—Every farm owner has a given amount of capital invested in land, and this money should bring a reasonable return each year. If the prevailing rate of interest is 8 per cent per annum, it will be apparent that a land valuation of $200 per acre should bring an interest return of $16 per acre. This interest is chargeable against the crop grown upon the land during the season. Since, on the farms studied, the beet land was given a higher valuation than other lands, sugar beets assumed a greater proportion of the interest cost than the remaining crop enterprises. Land rent is directly related to interest charges; however, it should be observed that the share or cash payment not only covers interest on the investment in such land, but also takes care of land taxes and insurance. This item was $1.68

per acre greater at Provo than at Garland. Idaho Falls growers were $4.49 below the highest average interest and rent charge.

On farms where the greater part of the hand labor is on a contract basis it is the custom for the sugar company to advance to the operator sufficient money to pay approximately one-half of the total cost of hand labor as soon as the thinning and hoeing have been completed. The amount of this loan, with interest, is deducted from the beet receipts in the autumn. This interest is a part of the cost of raising beets, and it has been so charged in this study.

Beet machinery cost per acre.—In computing the cost for machinery it is necessary to consider not only the interest on the original investment which was required to furnish field equipment for the production of sugar beets, but also depreciation and annual repairs. A part of the equipment used in the preparation of beet land is required in caring for other crops; hence the annual charge against these implements must be distributed as equitably as possible over the enterprises involved. These items were calculated and compiled as machinery charge. The method employed in securing the essential data in 1914 differed somewhat from the plan which was followed in 1915. The former plan gave a slightly lower charge than the latter, and the fact that the records for 1914 were confined to Provo and Garland explains in part why Idaho Falls has the maximum machinery cost. The difference between Garland and Idaho Falls was only 59 cents per acre. By comparing the machinery charge with other costs in this classification, or with the total cost of production, it will be observed that the equipment cost constitutes only a minor part, and any small modification one way or the other would not appreciably change the final results.

Miscellaneous expense.—There are certain other costs which are not chargeable to any one enterprise in particular, but have to be carried by the whole farm, and a certain part must fall upon each enterprise. To make provision for these items a 3 per cent charge was assigned on the basis of the labor and material costs combined. If the labor and materials amounted to $50 per acre, 3 per cent of this sum would be $1.50. The latter would then be counted as a part of the total cost of producing the crop. There is a difference of 16 cents between the Idaho Falls group and the average which was obtained from the Garland estimates.

SUMMARY OF COSTS.

TABLE XXVIII.—*Summary and distribution of costs.*

District.	Year.	Cost per acre.	Cost per ton.	Percentage distribution of costs.		
				Labor.	Materials.	Other costs.
Garland	1914–15	$69.03	$4.65	58.3	9.6	32.1
Provo	1914–15	69.59	4.65	54.4	10.0	35.6
Idaho Falls	1915	62.68	4.60	56.3	11.5	32.2

The average yield per acre for the 79 Garland reports was 14.85 tons; the 58 Provo records gave essentially the same average; while in the Idaho Falls district 36 farms showed an average return of 13.62 tons per acre. The cost per acre was $69.03 for the Garland area, slightly more for the Provo farms, and considerably less for the Idaho Falls group. There was very little difference in the cost per ton in the three areas. (See Table XXVIII.)

Labor is by far the largest item of expense in producing sugar beets. It constitutes from 54.4 to 58.3 per cent, or slightly more than half of the total cost. The purchase of materials takes approximately 10 per cent of the total amount, while other costs constitute about 33 per cent of the entire expense of production.

After the total costs had been determined these figures were compared with the returns from the crop. The total returns include not only the amount received for the beets, but also the value of the tops. (See Table XXIX.)

TABLE XXIX.—*Average returns and margin above cost in producing sugar beets, 1914–15.*

District.	Yield per acre.	Received per acre.	Cost per acre.	Net returns, beets per acre.	Total net returns per acre including tops.
	Tons.				
Garland	14.85	$74.40	$69.03	$5.37	$7.60
Provo	14.96	74.20	69.59	4.61	6.85
Idaho Falls	13.62	69.46	62.68	6.78	9.23

The receipts per acre for sugar beets depend upon the yield per acre and the price paid per ton. The yields were almost identical for the Garland and Provo sections, but the average for Idaho Falls was slightly less. There was practically no difference in the price paid per ton in the three districts.

LABOR REQUIREMENTS.

The labor requirements in producing sugar beets comprise three groups—namely, man, horse, and contract labor. Since it is a general practice to hire certain operations done at a stipulated price per acre or ton, the contract labor is always given in money values. In order to obtain the total man-labor requirement for the three districts under consideration, this cash outlay for contract work has been changed to its equivalent in man hours by dividing through with a rate of 25 cents per hour. The hours of man labor reported in Table XXX represent the total man labor necessary in the production of an acre of sugar beets under the conditions that obtained in this investigation.

TABLE XXX.—*Labor required in producing an acre of sugar beets.*

District.	Number of records.	Acreage grown.	Average yield per acre.	Hours of man labor.	Hours of horse labor.
Garland	79	1,461	14.85	133.3	98.5
Provo	58	833	14.96	130.8	117.14
Idaho Falls	36	735	13.62	119.4	79.3

The Provo and Garland districts have essentially the same man-labor requirements. Idaho Falls operators produced an acre of sugar beets with 11 to 14 less man hours than growers in the companion districts. It is of interest to note that the contract labor in the Provo area was about one-third that of the other areas. The major portion of the hand labor at Provo was performed by the farmer and his family and, as has been previously pointed out, was accomplished at a lower cost than would have been possible if done on a contract basis. This practice is feasible only where the farm units are small. In the other districts the farms are larger than at Provo.

The fewest horse hours were necessary at Idaho Falls and the most at Provo. This difference was due partly to the difference in acreage in beets in the different areas. More efficient use was made of horse labor on the larger beet tracts. The average acreage per farm in beets was 14.36 at Provo, 17.94 at Garland, and 20.40 at Idaho Falls. Larger crews were used in the Garland and Idaho Falls regions than at Provo, and this had a tendency to reduce the horse-labor requirement per acre.

VALUE OF TOPS.

More attention is being given annually to a better utilization of beet tops. This by-product is considered quite important by many growers. Other men attach very little value to them. In view of the fact that there is quite an appreciable waste under certain methods of handling beet tops, it is not surprising that opinions on the value of this feed should vary widely.

The field estimates in Utah and Idaho dealing with this subject can be divided into three distinct groups. On many farms the tops were fed to the live stock owned by the operator. The estimated valuation assigned on these farms was based upon the probable sale price of feeding stuffs which would be saved when tops were fed. Other growers in these districts sold the beet tops to cattle or sheep feeders, and the estimates in this instance were based upon the cash receipts for tops. The third group included those farmers who plowed the tops under. A few farms combined two of these methods in disposing of the beet tops. The per cent of farm estimates and the average value of the beet tops per acre under three methods of handling them are shown in Table XXXI.

TABLE XXXI.—*Disposition and estimated acre value of sugar beet tops.*

District.	Year.	Number of records.	Per cent fed.	Value when fed.	Per cent sold.	Value per acre when sold.	Per cent plowed under.	Value when plowed under.
Garland	1914–15	79	35	$2.48	19	$2.12	32	$1.77
Provo	1914–15	58	50	2.81			29	1.27
Idaho Falls	1915	36	61	2.31	31	2.82		

A much lower estimated value was reported by the farmers who plowed under the tops than by the men who fed or sold this material. In the Garland district the average cash price received per acre was less than the average estimated value. The case was reversed in the Idaho Falls district, and the operator who sold obtained a higher price per acre than the estimated value which was given by those men who fed the tops to their own live stock.

BEET ACREAGE PER FARM AND YIELD PER ACRE IN RELATION TO COST.

The yield per acre is an important factor in making a study of costs. The number of acres planted per farm also appears to exert some influence upon cost of production. (See Table XXXII.)

TABLE XXXII.—*Costs in relation to acres in beets and yield per acre.*

Acres in beets.	10 tons or less per acre (cost).			11 to 15 tons per acre (cost).			16 tons and over per acre (cost).		
	Number of farms.	Per acre.	Per ton.	Number of farms.	Per acre.	Per ton.	Number of farms.	Per acre.	Per ton.
10 acres or less	12	$62.59	$8.65	17	$72.47	$5.53	29	$75.70	$4.12
11 to 20 acres	14	59.04	6.69	24	66.87	5.01	32	71.81	3.93
21 acres and over	8	60.20	6.22	18	64.70	4.85	19	70.19	4.02

Increasing the yield per acre made the total cost per acre greater, but each successive increase in yield reduced the cost per ton. It would seem that the grower who is producing 16 tons per acre either in small, medium, or comparatively large tracts can grow and market these beets at a much lower cost per ton than the man who gets only 10 tons per acre under similar conditions. With greater efficiency in a few of the major operations, higher yields would undoubtedly result, and this in turn would appreciably increase the margin above cost. It may be noted that, with the exception of one subgroup, the larger the area devoted to beets, the less the cost per ton for a given yield. Where 21 acres of beets and over were grown and a yield of 16 tons and over was produced, the cost per ton ($4.02) was slightly increased by a lower yield per acre than that reported for the preceding size group.

COMPARISON OF BEET RECEIPTS WITH OTHER FARM RECEIPTS.

A comparison of the income from sugar beets with that from other farm enterprises sheds some light upon the importance of this crop, especially in the Provo and Garland areas. The information which was obtained upon the subject deals only with the crop year 1915. The average receipts per farm and the distribution of these receipts were obtained from 113 farms.

TABLE XXXIII.—*Beet receipts in comparison with other farm receipts.*

District.	Number of farm records.	Average total receipts per farm.	Per cent of total receipts from—				Per cent beet receipts are of total crop receipts.	Per cent receipts from potatoes are of total receipts.
			Crops.	Live stock.	Miscellaneous.	Beets.		
Provo	37	$2,542	54.1	43.4	2.5	41.8	77.2	
Garland	40	2,471	70.1	25.1	4.8	44.5	63.5	
Idaho Falls	36	4,873	64.8	34.1	1.1	29.4	45.3	24.4

A glance at Table XXXIII will show that the farms in these three districts were essentially crop farms. Approximately two-thirds of the returns from crops in the Provo and Garland districts came from sugar beets. This enterprise produced more than 40 per cent of the total farm receipts in the same areas. The lower returns from beets in the Idaho Falls section are due to competition with the potato. The receipts from potatoes and sugar beets combined were 53.8 per cent of the total receipts. The receipts from live stock in the Provo area came from dairy products, while at Idaho Falls these receipts were secured from sheep feeding.

RELATION OF YIELD TO COST OF PRODUCTION.

The accompanying frequency curve (Fig.9) shows the distribution of the operators in these three districts on the basis of cost per ton in producing beets.

It will be seen that the 173 operators who gave estimates may be divided into two groups, each including about an equal number of men. There were 89 men who produced sugar beets at a cost of $4.50 per ton or less, while 84 men raised sugar beets at a cost of $5 or more. The average cost for all farms was $4.64 per ton. The factories in these two districts paid from $4.85 to $5 per ton for sugar beets during the years 1914 and 1915.

It may be well to repeat, for the sake of emphasis, that the growers who produced the highest average yield per acre had the lowest cost per ton, whereas the men who obtained the lowest average yield had the highest cost per ton recorded against the crop. The yield per acre has a direct bearing upon the cost per ton.

On practically every farm there are places where the field work can be put upon a more efficient basis. Every grower is willing to concede that some slight change in present operations would probably be a step in the direction of greater crop yields. It has been pointed out that the sugar beet is not always grown in the regular cropping system. Continuous culture may, therefore, be holding down the yields; in other cases, a lack of fertility may be the controlling factor, although in all of these districts nearly every grower gave considerable attention to the application of farm manure. Inadequate preparation of soil or careless seeding may give poor stands. This precludes the possibility of a good yield. Furthermore, the blocking and thinning may be done in such a way as to interfere seriously with the stand. These are points which should be kept in mind throughout the season, and if there are weak places in the present methods of farm management, these should be corrected as far as possible.

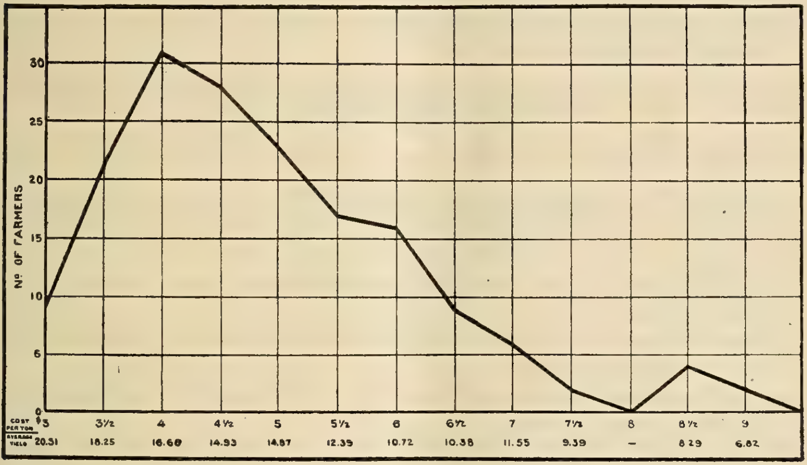

FIG. 9.—Frequency curve showing distribution of operators on basis of cost of beets per ton.

PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE RELATING TO THE PRODUCTION OF SUGAR BEETS.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

Profits in Farming on Irrigated Areas in Utah Lake Valley. (Department Bulletin No. 117.)

Loss in Tonnage of Sugar Beets by Drying. (Department Bulletin No. 199.)

Leafspot: A Disease of Sugar Beets. (Farmers' Bulletin No. 618.)

Control of the Sugar-Beet Nematode. (Farmers' Bulletin No. 772.)

Sugar-Beet Sirup. (Farmers' Bulletin No. 823.)

The Use of Windmills in Irrigation in the Semiarid West. (Farmers' Bulletin No. 866.)

Curly-Top of Beets. (Bureau of Plant Industry Bulletin No. 181.)

Conditions Influencing Production of Sugar-Beet Seed in United States. (Separate 503 from Yearbook 1909.)

PUBLICATIONS FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

Sugar-Beet, Culture, Seed, Statistics, etc. (Farmers' Bulletin No. 52.) Price, 5 cents.

Sugar-Beet Growing Under Irrigation. (Farmers' Bulletin No. 567.) Price, 5 cents.

Sugar-Beet Growing Under Humid Conditions. (Farmers' Bulletin No. 568.) Price, 5 cents.

Development of Single-Germ Beet Seed. (Bureau of Plant Industry Bulletin No. 73.) Price, 10 cents.

Curly-Top Disease of Sugar Beet. (Bureau of Plant Industry Bulletin No. 122.) Price, 15 cents.

American Beet-Sugar Industry in 1910 and 1911. (Bureau of Plant Industry Bulletin No. 260.) Price, 25 cents.

Biochemical Study of Curly-Top of Sugar Beets. (Bureau of Plant Industry Bulletin No. 277.) Price, 5 cents.

Comparative Tests of Sugar-Beet Varieties. (Bureau of Plant Industry Circular No. 37.) Price, 5 cents.

Progress Report of Beet-Sugar Industry in United States in 1909. (Report No. 92.) Price, 10 cents.

Analyses of Sugar Beets 1905–1910 With Methods of Sugar Determination. (Bureau of Chemistry Bulletin No. 146.) Price, 10 cents.

Report of Irrigation Investigations in Utah. (Office of Experiment Stations Bulletin No. 124.) Price, 90 cents.

Irrigation in Idaho. (Office of Experiment Stations Bulletin No. 216.) Price, 15 cents.

Utilization of Residues from Beet-Sugar Manufacture in Cattle Feeding. (Separate 137 from Yearbook 1898.) Price, 5 cents.

Relation of Sugar Beets to General Farming. (Separate 320 from Yearbook 1903.) Price, 5 cents.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 694
Office of the Secretary
Contribution from the Office of Farm Management
W. J. SPILLMAN, Chief

Washington, D. C. ▼ **July 24, 1918**

A STUDY OF FARM MANAGEMENT PROBLEMS IN LENAWEE COUNTY, MICH.

By H. M. Dixon, *Assistant Agriculturist*, and J. A. Drake, *Agriculturist*.

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OBJECT OF STUDY.

The basic data here presented were obtained in a survey of 300 owner farms and 153 tenant farms, located in Lenawee County, Mich. Later this work was supplemented by a special study of the more valuable farm practices of the region, special crops grown, and individual farms of more than ordinary merit.

The objects in view in conducting these investigations are in part as follows:[1]

(1) To obtain, through a close study, knowledge of some of the details of successful farming in an area typical of the northern edge of the corn belt.

(2) To determine the more important factors in the profitable management of the farms of this region.

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[1] Acknowledgment is due Mr. E. H. Thomson, assistant chief, Office of Farm Management, for selecting the area and planning the work; to Messrs. J. I. Falconer, L. G. Conner, H. M. Doyle, J. H. Hamilton, E. L. Moffit, and D. L. Cottrill, who assisted in collecting field data; and to H. W. Hawthorne, H. F. Williams, and J. C. McDowell for assistance in the preliminary work. Thanks are also extended to the many farmers of the region who have given the information which has made this publication possible.

The preliminary and basic data for this bulletin were gathered in 1912 and cover the farm year of 1911. It was planned to follow with a similar study five years later. In view of the abnormal conditions brought about by the war it has seemed more feasible to publish the findings as based on normal conditions. The basic data presented are supplemented with additional information gathered recently.

(3) To gather information regarding some of the more valuable farm practices in vogue on the better farms of the region and to suggest ways of improving the organization and management of the less successful farms in the light of the facts thus brought out.

SUMMARY.

The agriculture of Lenawee County has passed through several important changes but at present has become well established along the lines of general or diversified farming and dairying.

General farming with a limited amount of dairying is on the average the type most easily made profitable of those so far developed in the area studied.

Specialized dairy farms apparently pay better normally than dairy and grain farms, but on the average do not pay so well as the combination of dairying and hog raising.

Dairying, with hogs and grain, usually yields a better labor income than any other combination found. The outstanding advantages of this type as compared with others are a greater diversity of income, a large percentage of receipts from the sale of live stock and live-stock products, and a comparatively small percentage of the income from the sale of crops.

The types of farming established and the general conditions which prevail make the size of the farm a very important factor bearing on the returns secured from farming in this region. There is also a direct relation between the amount of capital invested and the labor income of the operator.

The 66 owner farms studied, with 60 acres and under and averaging 45 acres in area, made an average labor income of $277; the group of 124 owner farms from 61 to 100 acres and averaging 84 acres in area, made an average labor income of $445; and the group of farms of over 160 acres, averaging 223 acres in area, made an average labor income of $1,047. This shows the influence in the size of business as measured in terms of the size of the farms.

Sixty-seven farms, with an average investment of $4,850, made an average labor income of $276; 54 farms, with an average investment of $12,813, made an average labor income of $488; and 31 farms, with an average investment of $27,124, made an average labor income of $1,139. This shows the influence of the size of business as measured by capital invested.

Crop yields and the quality of live stock kept are two very important factors in efficient farm management which show a marked effect in the profitable management of the farms of Lenawee County. The quality of dairy cows or the income per cow is especially important on farms which are devoted largely to dairying.

A study of the relative percentage of acreage devoted to the principal farm crops indicates that under normal conditions there should be an increase in the acreage of corn on the average farm of the region. The average acreage of oats, wheat, barley, and hay are well within the limits shown to be most profitable.

Lenawee County is primarily a live-stock section and on most farms a greater percentage of the income is derived from the sale of live stock and live-stock products than from the sale of crop products. However, with but few exceptions, the better organized and more profitable farms of the section continue to receive from 10 to 30 per cent of their total income from the sale of surplus crops.

Corn, oats, wheat, and hay are the principal farm crops of the region. Of the special crops, alfalfa is by far the most important. This crop is rapidly gaining favor, and is found in small acreages on most farms of the section surveyed. Soy beans do well on all the soils of the county. This crop could be made valuable in the winter feeding of hogs and for starting feeder lambs in the fall. Cowpeas are especially suited to the sandy soils of the county.

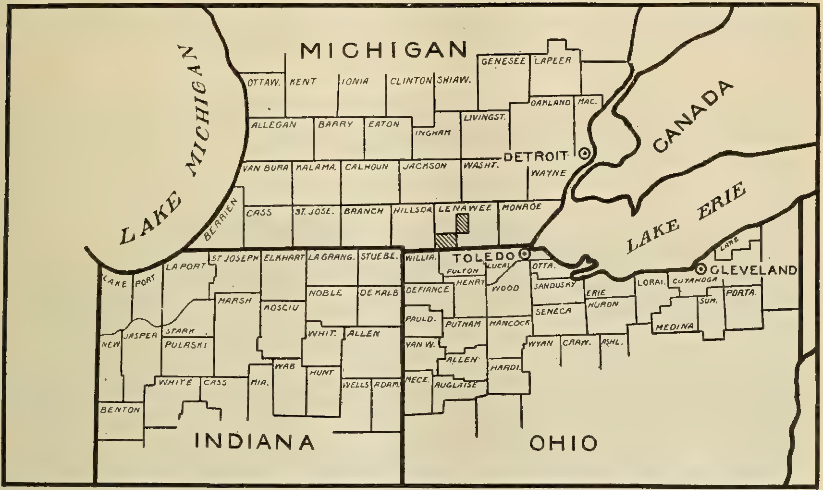

FIG. 1.—Location of the area studied (shaded portion of map).

In Lenawee County men with a capital ranging from $1,000 to $7,000 make better labor incomes by renting farms than by owning them. No tenants were found with a capital over $7,000, but up to this point the data show considerable advantage for the tenants as compared with men with an equal capital who own their farms. This is largely due to the fact that the rented farms are larger than the corresponding owner farms. The tenant with all his money used as working capital can conduct a larger business than he would be able to do if the same capital were divided between real estate and working capital.

DESCRIPTION OF AREA SURVEYED.

The area selected for this study is typical of a comparatively wide section of south central Michigan, a part of northwestern Ohio, and northeastern Indiana. It presents conditions which exist generally in that region situated on the northern edge of what is commonly known as the corn belt proper. The region in general is well developed in growing general farm crops, dairying, and the production of live stock. (Fig. 1.)

AGRICULTURAL DEVELOPMENT.

Lenawee County was one of the first counties in Michigan in which agricultural development started. The tide of immigration into this part of the State began on a large scale in 1836. From 1836 to 1860 the agricultural development of Lenawee County was rapid, and since that time it has been very satisfactory. Statistics show that there were 3,251 farms in Lenawee County in 1880, and that in 1910 this number has increased to 5,334. The county in general now has every evidence of a prosperous agricultural section. (See fig. 2.)

FIG. 2.—Typical farm scene, Lenawee County, Mich.

During the early period of development oxen were quite generally used for practically all kinds of farm work. In 1860 there were 2,247 work oxen in the county, but by 1900 oxen had been entirely displaced by horses. During this time large numbers of sheep were pastured on the cheap, partially developed land, which greatly increased the farm income and materially assisted in the process of land clearing. The sheep industry in Lenawee County appears to have reached the high-water mark in 1880, at which time there were 116,508 head of sheep on the farms of the county. The following figures taken from the United States census show the rise and decline of this industry in the county from 1860 to 1910:

Sheep.

	Number.
1860	89, 929
1870	112, 653
1880	116, 508
1890	110, 446
1900	103, 369
1910	90, 654

While land in general was low in price in Lenawee County, small grain, especially winter wheat, was grown on a large scale. Although wheat is still grown on a comparatively large acreage, the increased price of land has made more diversified farming a necessity. The period of the greatest wheat production in the county was between 1870 and 1890, reaching the highest mark in 1880, as is shown in the following figures taken from the United States census:

Wheat.

Year.	Bushels.	Year.	Bushels.
1860	423, 843	1890	719, 668
1870	685, 000	1900	321, 670
1880	1, 251, 479	1910	526, 628

Two once thriving industries, tobacco growing and hop production, practically have been abandoned. In 1860 Lenawee County produced 25,602 pounds of tobacco, and in 1880 this had fallen to 6,863 pounds. Now there is no commercial production of tobacco in the county. In 1870 the hop production of Lenawee County was 16,872 pounds, and in 1890 it was 3,500 pounds. This industry has since been apparently abandoned altogether.

The principal developments have been along the lines of general and diversified agriculture. The large holdings which predominated when the county was new have been broken up into farms of medium size. There has been a gradual and almost constant increase in corn, hay, hogs, and milch cows from 1860 up to the present time. This is shown by the following figures:

Production in Lenawee County, Mich.

Year.	Corn.	Hay.	Hogs.	Milch cows.
	Bushels.	*Tons.*	*Number.*	*Number.*
1860	1, 213, 311	47, 396	24, 762	11, 235
1870	964, 306	68, 332	25, 332	15, 772
1880	1, 759, 467	67, 944	62, 045	18, 943
1890	1, 480, 124	89, 442	67, 421	18, 943
1900	2, 053, 197	86, 387	63, 549	19, 519
1910	3, 053, 197	117, 132	77, 368	25, 924

These figures show at a glance the trend of agriculture in the county. It is plainly evident that developments have been in the direction of stable and conservative farming.

Road building in general has not reached as high a plane in Lenawee County as has agriculture. The average road of the county is only fair. There is now a general awakening to this fact and a few miles of first-class road have been built. In almost all parts of the county there is an abundance of gravel suitable for road building, which should assist greatly in the construction of good roads.

Rapid progress is being made in agricultural development. The county recently employed a county agricultural agent to assist in the solution of farm problems. Farmers' organizations are well represented. Granges, gleaners, agricultural clubs, and farmers' institutes are putting forth considerable effort for the general betterment of agricultural conditions in Lenawee County.

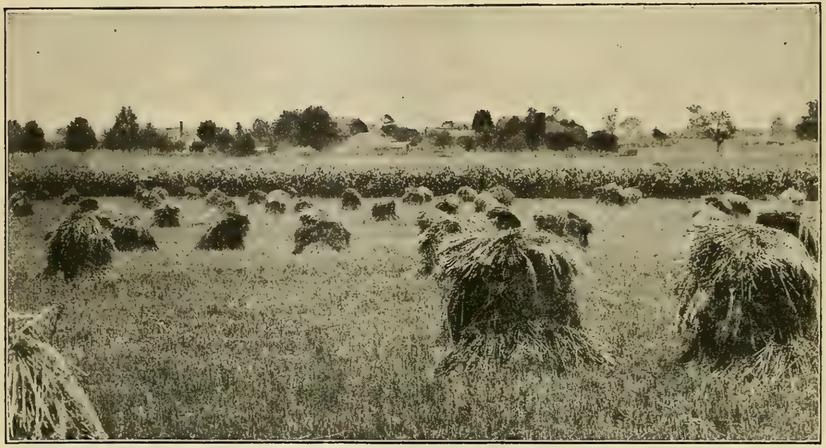

FIG. 3.—"The soil in general is well adapted to the growing of small grains and corn."

SOILS AND TOPOGRAPHY.

Most of the soils in the area surveyed are of glacial origin and very similar in nature to those which predominate throughout south-central Michigan. Similar soil also extends over into northwestern Ohio. The surface soil generally varies from a heavy silt loam to a clay loam. The subsoil is usually a clay or clay loam, but in local areas more or less gravel and occasionally some sand occurs. Viewed from the standpoint of farm land, a general uniformity of quality prevails. As a rule, the area is gently rolling, with good natural drainage and very productive. The soil in general is well adapted to the growing of small grains and corn and gives rise to conditions which are conducive to general farming. (See fig. 3.)

In the southeastern part of the county, however, the soil conditions are very different from those just discussed, and the results of this survey apply to this part of the county only in a general way. This section is a part of an old lake bed and naturally is very productive. The topography is very level and drainage has been difficult. Extensive systems of tile drains have been necessary in bringing most of the land under cultivation. Lying between this lake-bed section and the area surveyed more or less sandy land occurs, which corresponds generally to former shore lines. These sandy soils produce good crops during years of average rainfall.

AGRICULTURE OF THE AREA.

The agriculture of the area is general in nature. There is little tendency toward specializing on any one enterprise to the exclusion of others. General farming with reasonable amounts of live stock is the type which usually prevails. The organization of the average farm of the area includes most of the standard farm crops of the eastern half of the corn belt in fairly equal proportions, together with dairying and hog raising. In addition to the sale of live stock and stock products, considerable income is secured in this area from the sale of cash crops. Thus in this section there has been developed a well balanced and diversified agriculture.

DISTRIBUTION OF FARM CAPITAL.

In Table I is shown the distribution of capital on the owner and tenant farms covered in this study. The average investment on the owner farms in this area was nearly $12,000. Of this amount three-fifths was in land and one-fifth (22.6 per cent) in buildings. The dwellings averaged $1,311 and all other buildings $1,342 per farm. The rest of the farm investment was divided between live stock, machinery, feeds, and other supplies, of which about $1,261 was in live stock, $398 in machinery, and $393 in feeds, miscellaneous supplies, and operating cash.

TABLE I.—*Average capital and its distribution on 300 owner farms and 153 tenant farms, Lenawee County, Mich.*

	Capital per farm.						
	Owner farms.	Share-rent farms.			Cash-rent farms.		
		Total.[a]	Tenant's share.	Landlord's share.	Total.[a]	Tenant's share.	Landlord's share.
Average capital	$11,756	$14,521	$1,506	$13,015	$10,827	$1,765	$9,062
Per cent of capital invested in—							
Land	60.0	63.7		17.1	61.7		73.7
Dwellings	11.2	9.9		11.1	13.0		15.5
Other buildings	11.4	10.8		12.0	8.9		10.8
Live stock	10.7	9.7	59.3	4.0	10.5	64.6	
Machinery	3.4	2.8	25.8	.1	3.3	19.3	
Feed, other supplies, and cash	3.3	3.1	14.9	1.7	2.6	16.1	

[a] Capital of tenant farms includes both that of the tenant and the landlord.

The investment on share-rented tenant farms averaged nearly $3,000 more than on owned farms. The value of real estate per acre was practically the same on both owner and tenant farms. These share-rented farms have an average of 31 more acres per farm than the owner farms. There is no great variation in the distribution of capital on these farms from that on the owned farms. The landlord shares a part of the live-stock investment on all share-rented farms. The cows and hogs are usually shared equally, but the relative shares of each other class of live stock vary somewhat on each farm.

The cash-rented farms averaged 2 acres less in size than the owned farms, and the value of real estate per acre $5 less.

UTILIZATION OF LAND.

The area under discussion is well developed, the farms are well improved, and most of the land is utilized to good advantage. As will be seen by Table II, an average of 90.2 per cent of the total area of all the farms studied is improved land, only 2.9 per cent being woodland, and 6.9 per cent classed as other lands, which includes roads, fence rows, and waste lands in general. An average of 74.2 per cent of the total farm area of these farms is tillable, and 56.3 per cent is in crops. The table shows, further, that an average of 33.8 per cent of the total area of all the farms studied is in pasture. This acreage is made up of 10.6 per cent rotation pasture and 23.2 per cent permanent pasture, 7.2 per cent of the latter being tillable. As a rule the farms of different sizes show no material difference in these items, hence only the averages are given and these are for the entire number of farms.

TABLE II.—*Utilization of farm area on 300 owner farms and 153 tenant farms, Lenawee County, Mich.*

Average size .... acres	112
Percentage of total farm area in:	
Tillable area	74.2
Crop area	56.3
Idle crop land	.1
Total pasture	33.8
Rotation pasture	10.6
Permanent pasture	23.2
Permanent pasture, tillable	7.2
Total improved land	90.2
Woodland	2.9
Other land	6.9

Table III.—*Distribution of crop area on 300 owner and 153 tenant farms, Lenawee County, Mich., as compared with 1910 census figures for entire county.*

Crops.	Percentage of total crop area.		Crops.	Percentage of total crop area.	
	453 farms surveyed.	1910 United States census data for all farms in county.		453 farms surveyed.	1910 United States census data for all farms in county.
Corn for grain	26.2		Oats	17.5	20.0
Corn for silage	2.2		Barley	2.0	2.7
Other corn	1.1		Other grain [a]	.5	.8
			Hay	28.8	30.8
Total corn	29.5	28.6	Alfalfa	1.6	.4
			Other hay [b]	1.0	2.0
Potatoes	.6	1.5	Truck	.1	.9
Winter wheat	14.2	8.7	Fruit	3.5	2.7
Spring wheat	.7				

Average crop area, 56 acres.

[a] Includes speltz, oats and barley, rye, buckwheat, oats and peas, peas and beans, clover and timothy seed.
[b] Millet, oats and peas, oat hay, barley, sorghum and rape.

Table IV.—*Yields of crops on 300 owner and 153 tenant farms, Lenawee County, Mich.*

	Corn for grain.	Corn for silage.	Potatoes.	Wheat.	Oats.	Barley.	Hay.
	Bushels.	*Tons.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Tons.*
Owner farms	54	10	85	23	40	24	1.1
Share-tenant farms	54	10	86	21	41	25	1.1
Cash-rent farms	51		82	22	38	22	1.0

Table IV shows the average yield of the principal crops grown in this area on farms operated by both owners and tenants.

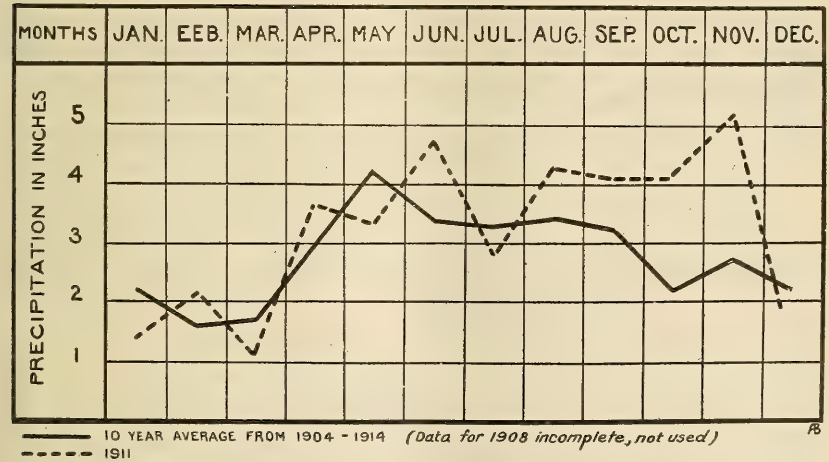

Fig. 4.—Rainfall in Lenawee County for year 1911, as compared with 10-year average (1904–1914).

A comparison of the yields received upon the owned and share-rented farms shows only a slight advantage to the share-rented farms. The cash-rented farms are producing the lowest yields.

The rainfall for the year 1911, as compared with the 10-year average (1904–1914), is shown in figure 4.

CROPS.

Hay and corn lead all other crops in area, the former on the average covering a slightly greater acreage than the latter. On the entire number of farms studied hay crops occupy an average of 31.5 per cent and corn 29.5 per cent of the total crop area. The oats crop is third in importance, occupying 17.5 per cent of the total crop area, with wheat fourth, occupying 14.9 per cent. A number of other crops are grown, but none is of great importance. Table III shows the distribution of the various farm crops on 300 owner farms and 153 tenant farms in Lenawee County. It likewise shows the same data as gathered on all farms of the county in the census of 1910. It will be observed that in a general way the data correspond very closely. Figure 5 shows graphically the percentage of the total crop area which each crop occupies and the average per farm on these same farms.

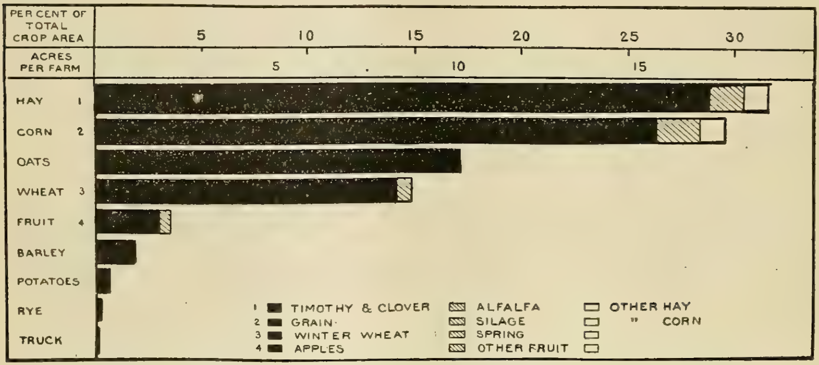

FIG. 5.—Acreage of the more important crops, 300 owned and 153 tenant farms, Lenawee County, Mich.

TABLE V.—*Distribution of live stock on 300 owner and 153 tenant farms, Lenawee County, Mich.*

Class of live stock.	Average number per farm.	Average animal units per farm.	Per cent of total animal units.	Class of live stock.	Average number per farm.	Average animal units per farm.	Per cent of total animal units.
Cows	8.4	8.4	38.7	Horses[a]	3.4	3.4	15.7
Young stock	2.6	1.3	6.0	Sheep	12.5	1.8	8.3
Bulls	.4	.4	1.8	Feeding sheep	4.7	.7	3.2
Beef stock and feeding steers	.3	.3	1.4	Brood sows	2.3	.5	2.3
				Other hogs	17.0	3.4	15.7
Colts	.6	.3	1.4	Poultry	115.0	1.2	5.5

[a] Work horses averaged 3.3 per farm and are included in this table.

LIVE STOCK.

Dairy cows are the most important kind of live stock on the average farm of this immediate section Hogs are second in importance and horses third. Table V shows the average number of the different kinds of live stock and their equivalent in terms of animal units[1] per farm. The relative importance of each class of live stock expressed in percentage of total animal units is also shown in the last column of this table.

On these farms there was an average of 8 cows per farm, which constituted 38.7 per cent of the total animal units kept. Brood sows averaged over 2 per farm and other hogs 17, all kinds together constituting 18 per cent of the total animal units. Horses constituted over 15 per cent. Sheep made up an average of 11.5 per cent and young stock of the dairy herd 6 per cent. It is worthy of note that poultry averaged 115 head per farm, or 5.5 per cent of the total animal units.

SOURCES OF INCOME.

Further light on the general character of the agriculture of the region is gained by a study of the sources of income. Taking an average of 300 owner and 153 tenant farms which were studied dairy products constitute the largest source of income. Hogs ranked second, and wheat third, with the income from poultry ranking a close fourth. Table VI gives in detail the proportion derived from the different sources on all farms studied. Figure 6 shows graphically the relative importance of these different sources of income. Less than one-fifth of the farm receipts are from the sale of crops. Sales of crops were practically the same on owner and tenant farms.

TABLE VI.—*Average per cent of total farm receipts from different sources, 300 owner and 153 tenant farms, Lenawee County, Mich.*

Sources of income.	Per cent of total receipts.	Sources of income.	Per cent of total receipts.
Dairy products	31.8	Corn	1.3
Dairy cattle	5.4	Potatoes	.6
Beef cattle and feeding steers	.7	Wheat	7.9
Horses	.3	Oats	3.8
Colts	2.0	Barley	.7
Sheep	3.6	Other grain	.1
Feeding sheep	1.9	Hay	3.6
Hogs	15.4	Seeds	.2
Poultry	6.9	Truck	.4
		Fruit	.9
Total live stock	68.0	Miscellaneous[a]	3.5
		Feed and supplies[b]	9.0

[a] Labor, lumber or wood sold, etc. [b] Increase inventory.

A study of Table VI shows that dairy products brought nearly one-third (31.8 per cent) of the total receipts of the 453 farms studied. Hogs stood second in importance, receipts from hog sales averaging 15.4 per cent of the total. Wheat brought 7.9 per cent, and it is worthy of note that the sale of poultry and poultry products accounted for 6.9 per cent, almost as much as the receipts derived from sale of wheat. The table shows further that on the average only small quantities of oats and hay are sold, the oat crop bringing only 3.8 per cent of the total receipts, and the sale of hay only 3.6 per cent. Since hay occupied 31.5 per cent of the total crop area on these farms (see Table III) and the oats crop 17.5 per cent, it is evident that the greater part of these crops are consumed as feed on the average farm of the area.

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[1] An animal unit is a mature horse or cow or as many smaller animals as require the feed of a horse or cow, namely, 2 head of young cattle, 5 hogs, 7 sheep, or 100 hens.

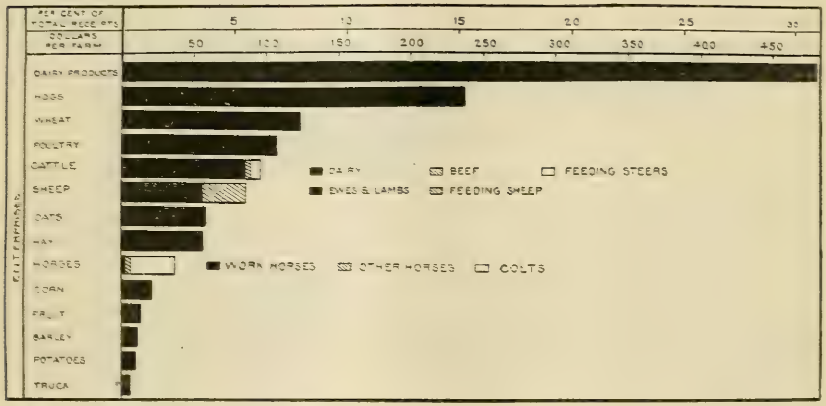

FIG. 6.—Sources and amount of receipts, 300 owned and 153 tenant farms, Lenawee County, Mich.

FACTORS OF ORGANIZATION AND MANAGEMENT.

There are a number of factors which enter materially into the successful organization and management of farms. Some of these factors are of greater importance than others, some may be disregarded without serious consequence; but as a rule the profit derived from farming depends very largely upon the extent to which certain essential features of organization and management have been adopted and adhered to.

One of the first of these factors to be considered is the type of farming, with reference to local soil, climatic, and market conditions. Of the different types which suit these conditions, selection should be made not only in view of the greatest profits but also to suit the individual likes and dislikes of the operator.

Another important factor is the size of the farm business which it is possible to develop on a given area. A large volume of business may be done on a small farm while only a small business may be conducted on a large farm if poorly managed. Without reasonable size of business there is little opportunity for a satisfactory profit in farming. How this factor affects the farming operations of Lenawee County will be discussed in detail later.

"Quality" is a general term given to a number of essential factors which affect the farm business from the standpoint of production. Quality used in this sense is exemplified in the yield of crops and the producing capacity of live stock. In regard to crops, maximum yields are sometimes expensive and not desirable, but under the conditions that prevail in this area, unless the soil produces fair yield without the use of expensive fertilizers, there is little basis for profitable farming. On farms where live stock are kept this live stock must be of good quality and efficiently handled. On farms where dairying is an important enterprise the quality of the cows, as measured by the amount of milk produced per cow, is one of the most important factors of success. How these important items influence the returns on the farms studied in this area will be shown later.

TYPE OF FARMING.

The farms studied in Lenawee County fall under four fairly distinct classes or types, according to predominating enterprise or combination of enterprises on which the general organization is founded. On this basis were found farms devoted principally to dairying, hogs, and grain; dairying and hog raising; dairying alone; and dairying and wheat production. In each of these classes, however, dairying is of considerable importance (see fig. 7). It is interesting to note that, even with this very general classification, a study of the data gathered shows there is a distinct relation between the type of farming and labor income. For this study 213 of the owner-farms were selected which conform most naturally to this classification. The results of this arrangement of data are given in Table VII.

FIG. 7.—Scene on Lenawee County farm on which dairying is combined with grain farming.

TABLE VII.—*Relation of type of farming to amount of capital used and labor income on farms operated by owners, Lenawee County, Mich.*

Type of farming.	Number of farms.	Average investment.	Average labor income.
Dairying, hogs, and grain	114	$12,897	$626
Dairying and hogs	54	10,974	433
Dairying	28	12,640	378
Dairying and grain	17	12,522	278

Since the capital invested averages about the same for each of these groups of farms, the influence of the size of business as measured by capital is practically eliminated. It is therefore fair to conclude that the difference in labor income is largely, if not altogether, due to the type of farming. The farms operated with dairying, grain, and hogs as the leading enterprises returned their operators the largest incomes. After taking out 5 per cent on the investment, these farms had an average labor income of $626 clear of all expenses. On the same basis the dairy and hog farms made an average labor income of $433. The 28 farms classed strictly as dairy farms made an average labor income of $378. The lowest average labor income was made by the combination dairy and grain farms, namely, $278. The figures given in this table are representative of normal conditions, but dairy and grain farming, especially with grain production predominating, would show decidedly different results during the abnormally high prices of 1916–17.

The farms classified under the heading "Dairying, hogs, and grain" are practically of the type ordinarily classed as general, or diversified. Besides having the three more important enterprises, these farms have a greater use for small enterprises than the more specialized farms, thereby enabling them to use capital and labor to better effect. This type is most prevalent in this section, and the figures given confirm the apparent belief of the farmers of the region that the general farm, with a limited amount of dairying, is under normal conditions the most profitable type of farm organization so far developed there. Diversity is an important factor which helps to make these general farms profitable and comparatively certain of income. This is brought about not only through the larger number of sources from which the income is derived, but by reason of the fact that this type is less subject to fluctuations from year to year than the specialized type.

There are comparatively few farms in this area which may be classed as dairy and grain farms. Specialized dairy farms are slightly more numerous than dairy and grain farms and under normal grain prices have a slightly higher average labor income.

An idea of the organization of the farms of these different types may be gained from a study of the source from which income is derived. Table VIII shows the average percentage of receipts derived from the different sources for each of the different types or classes.

TABLE VIII.—*Source of income and percentage of income from each source, 213 owner farms of different types, Lenawee County, Mich.*

	Sources of income on farms following each given type of farming.			
	Dairying, hogs, and grain.	Dairying and hogs.	Dairy.	Dairying and grain.
Number of farms	114	54	28	17
Per cent of income from—				
Dairy products	25.4	37.3	49.8	39.7
Dairy cattle	4.6	6.7	8.2	4.3
Beef cattle and feeding steers	.5	....	....	....
Horses	.2	.7	.6	1.0
Colts	1.8	2.1	2.2	1.2
Ewes and lambs	4.7	2.2	1.2	1.1
Feeding sheep	3.5	.1	....	....
Hogs	14.0	25.3	8.2	9.4
Poultry	7.1	7.2	6.6	5.4
Total live stock	61.8	81.6	76.8	62.1
Corn	2.2	.8	.1	2.0
Potatoes	1.5	.3	....	.2
Wheat	10.5	4.0	4.6	18.8
Oats	5.0	1.7	1.5	8.7
Barley	.6	.1	.5	3.7
Other grain	.4	.3	.2	....
Hay	.46	1.0	2.6	.8
Truck	.7	.1	.2	....
Fruit	.8	.6	.1	.1
Feed and supplies	8.3	7.3	10.0	3.2
Total crops and feed	34.6	16.2	19.8	37.5
Miscellaneous [a]	3.6	2.2	3.4	.4

[a] Includes man and team labor, machine work, sale of lumber, sale of sirup and sugar, rent of buildings, and cider making.

It will be seen that the farms classed as "dairy, hogs, and grain" derive only about one-fourth (25.4 per cent) of their incomes from the sale of dairy products; 14 per cent from the sale of hogs; and 10.5 per cent from the sale of wheat. The minor sources of income are as follows: Poultry, 7.1 per cent; oats, 5 per cent; dairy cattle, 4.5 per cent; hay, 4.6 per cent; ewes and lambs, 4.7 per cent; and feeding sheep, 3.5 per cent. It will be noted that these farms show distinctly a wider diversity in their sources of income than any of the other classes.

The dairy and hog farms receive 37.3 per cent of the total receipts from the sale of dairy products and 25.3 per cent from hogs, and the dairy and grain farms an average of 39.7 per cent of the total receipts from the sale of dairy products, and 18.8 per cent from the sale of wheat.

Looking in a general way at the organization of the farms of the area studied and the types of farming established, some important features are brought out in regard to the relative amounts of crops and live stock sold. In some sections and under some conditions it is best to sell practically all crops, while in others it is better and more profitable to derive the greater part or almost all the income from live stock. The size of farm undoubtedly has some bearing upon this phase of the farm business. (See Table IX.)

TABLE IX.—*Relation of per cent of total receipts from live stock to profits on 300 owner farms, Lenawee County, Mich.*

Per cent receipts from live stock.	Number of farms.	Acres per farm.	Crop index.	Receipts per productive animal unit.[a]	Average labor income.
Under 50	47	94	104	$51	$504
50 to 59	41	105	107	56	535
60 to 69	57	120	100	63	666
70 to 79	75	110	102	63	432
80 to 89	49	95	98	68	430
90 and over	31	86	92	62	237
All owner farms	300	104	100	61	481

[a] Includes all live stock on the farm excepting work stock.

Of the 300 owner farms studied the greater number received relatively a large proportion of their receipts from live stock, so that the variation in this respect is very wide. The farms which received 50 per cent and less of their income from live stock show slightly lower average labor incomes than those that received from 50 to 70 per cent of their income from this source. In this, however, it must be borne in mind that the farms receiving 50 per cent and less are comparatively smaller. In this connection it is difficult to draw any hard and fast conclusions, but it seems quite worthy of note that the most prosperous of the owner farms of the area studied are getting from 50 to 70 per cent of their income from the sale of live stock and stock products. In special cases and with farms of peculiarly radical departures in organization it is quite probable that the percentage of receipts from live stock may well be higher than normally found.

A similar condition arises in the study of the relative per cent of total receipts received from the sale of crops, as shown in Table X.

TABLE X.—*Relation of per cent of total receipts from crops to profits on 300 owner farms, Lenawee County, Mich.*

Per cent receipts from crops.	Number of farms.	Acres per farm.	Crop index.	Receipts per animal unit.	Average labor income.
None	46	91	96	60	$276
Under 10	64	93	99	66	455
10 to 19	66	110	102	65	636
20 to 29	66	117	104	61	569
30 to 39	30	108	103	54	503
40 to 49	16	111	106	54	324
50 and over	12	83	101	39	231
All owner farms	300	104	100	61	481

The farms which show the higher labor incomes are making from 10 to 40 per cent of their total income from the sale of crops, and it will be noted also that most of the farms in the list fall between these limits. Here, again, there is a direct relation between labor income and size of farm. Yields, too, as indicated by crop index, are somewhat higher on the more profitable farms. It is interesting to observe, however, that on the farms where more than 40 or from 40 to 50 per cent of the income is derived from the sale of crops, even with the average size of farms remaining about the same and the yield of crops slightly better, the average labor income falls off materially. The results given in both Tables IX and X can at best only serve as a very general guide in the organization of the farms of different types and sizes under average conditions, which exist normally in the area surveyed and in nearby sections.

SPECIAL FARMS.

In this region, as in most others, an occasional farm is found which departs widely from the type which investigations show to be that best adapted to the average conditions of the area, and yet is a pronounced success.

An example of this was found in a farm located on the heavier type of soil in Lenawee County on which alfalfa is easily grown. About 40 per cent of the crop area was in corn, 10 per cent in a nurse crop for alfalfa, and 50 per cent in alfalfa. In the winter season a large number of western lambs were fed. From a financial standpoint the results on this farm are decidedly satisfactory.

The management of such a farm, however, requires considerable skill and business ability. One of the principal difficulties arises from the fact that the labor is unequally distributed throughout the year. When alfalfa occupies the place in a farm system that it does in this instance it is necessary to provide a separate equipment in teams and implements and a separate group of men to take care of the alfalfa. Hence the equipment and crews needed during the summer months on such a farm are about double those demanded by the system which the farmers here have worked out by experience. Only about one half of the labor required can be given employment throughout the year. The other half is needed only in the summer and from the nature of the case must be temporary labor, which is usually unsatisfactory. If some means could be devised to give profitable winter employment to the surplus labor needed during the summer season, this system would work without any special difficulties other than those attending the fluctuation in the price of productive live stock to which the crop products are fed. To be successful with such a system, however, the farmer must be an expert buyer and seller and must have a thorough knowledge of the feeding qualities of livestock.

Another rather extreme instance was found in a large farm with land which for the most part is sandy. The farmers of the county have generally failed with alfalfa on sandy soils, but practically the whole of this farm is in alfalfa, there being no other crop. The owner feeds practically all the alfalfa to western lambs, buying the necessary grain to feed with it. This farm is usually very profitable, but it must be borne in mind that the owner is distinctly an expert in buying and selling lambs. Furthermore, his system enables him to utilize to excellent advantage second-grade alfalfa hay which would otherwise be unsalable. It may be noted also that on this farm there was a considerable area of alfalfa several years old with a compact bluegrass sod covering the field and yet making very satisfactory yield of hay. There is little question, however, that if the average farmer on sandy lands in Lenawee County were to attempt this same kind of farming he would fail; first, because of the admitted difficulty of growing alfalfa on sandy land; second, because of the lack of the expert knowledge required to make a success in the feeding of sheep.

These two farms merely illustrate the fact that the man who is distinctly above the average in ability and training in some special line is not limited by conditions which the average farmer may find insurmountable.

POULTRY.

There were no specialized poultry farms encountered in the area surveyed. However, the income from poultry on the farms studied was 6.9 per cent of the total income (Table VI) and only 1 per cent less than the income from the wheat sold. The data show that the farms receiving a small per cent of their total incomes from poultry made higher labor incomes than those which kept no poultry, and higher also than the farms which kept more. This merely means that on the average farm of the section it pays to keep from 100 to 200 hens, or about as many poultry in the aggregate as can be kept mainly on the farm wastes. When the number gets beyond this, poultry raising will not as a rule be profitable unless the farmer has the skill of a professional poultryman.

SIZE OF FARM BUSINESS.

The size of business conducted is as a rule a very important factor in determining the income of the average farm. Unless there is a reasonably large volume of business, there is not sufficient foundation for a satisfactory income. A large business when properly conducted gives opportunity for getting large returns, and in a similar manner, if inefficiently conducted, a large business affords an opportunity for suffering correspondingly large losses. This holds true in farming quite as well as in other lines of enterprise.

There are a number of ways of measuring the size of a farm business. When the type of farming is quite uniform, and the region well developed, and when there is little variation in the quality of the soil, the size of business may be accurately measured by the total area of the farm. Other methods of measuring the size of farm business are by capital invested and labor requirements.

SIZE OF FARM.

In most sections similar to Lenawee County, where the general type of farming prevails, there is a strikingly direct relation between the size of the farm and the net returns. Larger acreages up to certain limits permit a better utilization of labor and machinery. With the types of farming thus far developed in this area, a large acreage devoted to a general type of farming, with adequate machinery, and with a reasonable profit per acre, usually brings in a greater income for the owner or operator than a small farm handled more intensively and with relatively greater expense for hired labor.

TABLE XI.—*Relation of size of farm to income on 300 owner and 153 tenant farms, Lenawee County, Mich.*

Size of farm.	Working owners.				Tenants renting for cash.				Tenants renting on share.			
	Number of farms.	Average size of farm.	Average farm income.	Average labor income.	Number of farms.	Average size of farm.	Average farm income.	Average labor income.	Number of farms.	Average size farm.	Average farm income.	Average labor income.
		Acres.				*Acres.*				*Acres.*		
60 acres and less	66	45	$540	$277	7	38	$500	$456	4	37	$278	$249
61 to 100 acres..	124	84	922	445	14	86	730	648	35	84	526	474
101 to 160 acres.	72	129	1,172	434	8	131	728	614	57	133	630	553
Over 160 acres..	38	223	2,272	1,047	4	216	1,214	1,078	24	230	889	777
All farms.	300	104	1,069	481	33	102	739	651	120	125	640	564

Table XI shows the influence of the size of farm on labor income for both owner farms and tenant farms studied. The average farm income of the 300 working owners advances rapidly and uniformly as the farms increase in size, likewise the average labor income increases rapidly until the farms reach 100 acres in size, remains about constant for the next higher size-group and again increases rapidly in the group of farms above 160 acres in size. The 66 farms of 60 acres and less, and an average of 45 acres each, made clear of expenses an average farm income of $540, and after deducting 5 per cent interest on the investment made an average labor income of $277. The 124 farms in the size-group of 61 to 100 acres, and an average of 84 acres in size made an average farm income of $922 and an average labor income of $445. The 72 farms, 101 to 160 acres, averaging 129 acres, made an average farm income of $1,172 and an average labor income of $434; and the 38 farms over 160 acres, averaging 223 acres in size, made an average farm income of $2,272 and an average labor income of $1,047. The table also shows that the average farm and labor incomes of the cash and share tenants increase with the size of farms in about the same proportions.

The figures in Table XI show beyond question that under the conditions which exist in the area covered in Lenawee County and with the types of farming established, there is a decided increase in net returns and a general advantage in operation as the size of farm increases, at least up to the limit reached in this table. This fact presents for the consideration of each farmer in the region the problem of whether his farm business, as measured by the size of his farm, is of sufficient magnitude to permit him to earn a reasonable and adequate income. If not, it is well for him to consider ways and means of increasing the size of the farm or of getting the equivalent of an enlarged farm area. Naturally one of the first ways to suggest itself is to buy more land, if possible. If this is out of the question, similar results may be secured by renting additional land. If it is impossible to purchase or rent more land, then the nearest equivalent to an enlarged area is to increase materially the yields on the land already owned and operated, and in addition, improve the quality, and possibly increase the quantity, of the live stock kept. In enlarging a farm business in this manner care must always be exercised to see that the expense of increasing the yields and improving the live stock is not too great.

The large farms in this section on the average are yielding the greatest labor incomes for their owners and operators, but large farms in general require good management also. Ordinarily the man with small capital should first buy a farm of moderate size, but occasionally men who are good managers find it easier to pay for a big farm than a smaller one.

CAPITAL INVESTED.

As a rule there is a tendency to buy land before sufficient capital has been accumulated. To be limited in capital not only limits the acreage of the farm, but often hinders greatly the proper operation of the farm in general. Too often the purchaser fails to take this into account. While it is not advisable to carry too heavy an obligation, generally it is better to secure sufficient capital on a reasonable farm-loan basis than to operate too small a farm or be hampered by lack of operating capital. On the average, in Lenawee County, there is a direct relation between the capital invested and the labor income received.

TABLE XII.—*Relation of capital to labor income on 300 owner farms, Lenawee County, Mich.*

Capital.	Number of farms.	Average size of farms.	Average capital.	Average labor income.
		Acres.		
$7,000 and less	67	50	$4,850	$276
$7,001 to $11,000	109	83	9,033	386
$11,001 to $15,000	54	109	12,813	488
$15,001 to $20,000	39	154	17,550	569
Over $20,000	31	220	27,124	1,139
All farms	300	104	11,756	481

By a study of Table XII it will be seen that with but few exceptions, labor income keeps pace with the increase in capital in the different groups. Throughout the table there is an almost constant increase in the average labor income as the average investment increases. Beginning with the first group of 67 farms with $7,000 and less in capital, and an average investment of $4,850, the average labor income is $276 per farm; whereas, in the last group of 31 farms, with an average investment of $27,124, the average labor income is $1,139 per farm. This table emphasizes the importance of size of the farm business as measured by the capital invested.

EXPENSES.

It is to be expected that as the size of the farm increases the expenses must accordingly become greater. While this is true, the operating expenses and the expense of upkeep and repairs are normally less per acre on a large farm than on a small one. Here, again, the size of business becomes a factor in efficient and profitable management.

TABLE XIII.—*Relation of size of farm to annual cost of buildings, fences, and machinery per farm and per acre on 300 owner-farms, Lenawee County, Mich.*

	All farms.	Farms with each specified acreage.			
		60 acres and less.	61 to 100 acres.	101 to 160 acres.	Over 160 acres.
Number of farms	300	66	124	72	38
Annual cost per farm:					
Buildings	$143.00	$99.00	$128.00	$164.00	$226.00
Fences	19.00	14.00	16.00	25.00	27.00
Implements and machinery	26.00	14.00	23.00	32.00	50.00
Total	188.00	127.00	167.00	221.00	303.00
Annual cost per acre	1.81	2.85	1.99	1.71	1.36

Table XIII shows the relation of size of farm to expenses, including interest, general repairs, cost of farm buildings and machinery, and cost and repairs of fences on 300 owner-farms. It will be seen that the annual cost of buildings, fences, implements, and machinery per farm increases, and for all these items combined the annual cost per acre decreases, as the farms become larger. On the 66 farms of 60 acres and under in area, the annual cost per farm was $127 and the total annual cost per acre was $2.85; on the 124 farms of 61 to 100 acres in area, the annual cost per farm was $167 and the annual cost per acre was $1.99; on the 72 farms of 101 to 160 acres in area, the annual cost per farm was $221 and the annual cost per acre was $1.71; and on the 38 farms of 160 acres and over in area the annual cost per farm was $303 and the total annual cost per acre was $1.36.

QUALITY OF FARM BUSINESS.

Quality, as shown in the yield of crops and the income per animal unit, and especially the income per cow, exerts a great influence on the income derived from the farms of Lenawee County. From these standpoints there are marked differences in the farms surveyed. While the crop yields on the average are good, there are numerous farms on which the yields of practically all crops are much below the average, and other farms on which the crop yields are far above the average. There is a great variation also in income per animal unit and the income per cow. This makes it possible to show the contrast in labor income as affected by these factors.

CROPS AND LIVE STOCK.

In studying the data secured from a survey of this nature it is not an easy matter to separate entirely the two important factors of crop yields and income per animal unit; hence it is necessary to present the two together. Table XIV shows the combined effect of crop yields and live stock on the 300 owner-farms, but the arrangement of the figures makes it possible to study the influence of each independently of the other.

TABLE XIV.—*Relation of receipts per animal unit and yield of crops to labor income 300 owner farms, Lenawee County, Mich.*

Receipts per animal unit.[a]	Farms with crops yielding below the average for all farms studied (less than 100 crop index).				Farms with crops yielding above the average for all farms studied (more than 100 crop index.)			
	Number of farms.	Average size of farm.	Average number of animal units.	Average labor income.	Number of farms.	Average size of farm.	Average number of animal units.	Average labor income.
		Acres.				*Acres.*		
$40 and less	33	92	13	−$100	14	102	21	$192
$41 to $60	51	96	15	226	47 (46)	120 (108)	21	523 (509)
$61 to $80	61	105	16	482	56	107	18	718
Over $80	11	94	15	829	27	100	18	1,117
All farms	156	98	15	300	144	110	20	678

[a] Animal unit defined on page 14.

The 300 farms are divided into two groups on the basis of crop yields and into four groups on the basis of the receipts per animal unit. The first division on the crop basis includes all farms which have a crop index rating below 100, i. e., the farms that are making yields below the average of all the farms studied for that year; the second division includes all farms with a crop index rating above 100. The farms making $40 and less per animal unit and with crop yields below the average, lacked $100 per farm (minus $100 labor income) of paying all expenses and 5 per cent interest upon investment, while those of the same quality of live stock but with crop yields above the average made an average labor income of $192. Thus the difference in crop yields in the groups making $40 and less per animal unit, made a difference of $292 in the average labor income for each farm. In the next group of farms, those making from $41 to $60 per animal unit, the difference in the average labor income per farm was $297, in favor of those with good crops. The average size of the farms is greater in the latter case, (120 as compared with 96 acres.) This was due to the fact that the largest farm of the survey, one of 675 acres, fell in this class. With this farm omitted, the figures shown in the table in parentheses would have been the result; the average size would have been but 108 acres and the average labor income only slightly less, or $509. In the group of farms making from $61 to $80 per animal unit, the average acreage is practically the same and the average labor income of the farms with crop yields below the average is $482, as compared with $718 for those with crop yields above the average. With the average acreage about the same in the group receiving over $80 per animal unit, there is a difference in average labor income of $288 in favor of those farms having the better crop yields. Taking all farms, with an average difference of but 12 acres and 5 animal units per farm, there is average difference of $378 in labor income in favor of the farms with crop yields above the average.

The influence of good live stock on the average labor income of the 300 owner-farms studied may be seen first in the farms having poor crop yields, (less than 100 crop index) or which were below average of the area in crop yield, and those that were above the average in crop yield for that year (above 100 crop index). When the receipts increase from $40 and under per animal unit to over $80 per animal unit there is a gradual increase in the average labor income from minus $100 to plus $829 in the farms below the average in yield; while in the farms with crop yields better than the average there is an increase in the average income per farm from $192 to $1,117. Further study of the data presented shows that the size of farm and several important factors other than the two on which this tabulation is based, are practically the same for the different groups; hence it seems fair to conclude that quality as expressed in crop yield and income per animal unit are important factors which materially influence the incomes derived from the farms of this section.

INCOME PER COW.

On farms devoted largely to dairying, perhaps there is no other one factor of such great importance and none with so direct a bearing on labor income as the income per cow. In practically all of the studies of this character which have been made, this fact stands out with great prominence. In the survey of Chester County, Pennsylvania, for instance, the income per cow was shown definitely to be one of the more important factors of success on the dairy farms of that section. A table showing the figures in this connection are given in United States Department of Agriculture Bulletin No. 341, page 77. In a similar manner, also, the data gathered in the study of Lenawee County, Michigan, show that labor income on dairy farms of that section bears a direct relation to income per cow.

TABLE XV.—*Relation of receipts per cow to labor income, 212 owner-farms, Lenawee County, Mich.*

Receipts per cow.	Having 5 or more cows.				
	Number of farms.	Average of number of cows.	Average size of farms.	Average receipts per cow.	Average labor income.
$40 and less	38	8	113	$29	$245
$41 to $50	37	9	104	46	361
$51 to $60	35	10	132	56	401
$61 to $70	37	9	105	65	542
$71 to $90	41	11	133	79	915
Over $90	24	10	113	105	1,053
All farms	212	9	117	61	564

In Table XV is shown the relation of receipts per cow to labor income on the owner-farms covered in this study. The 38 farms with average receipts of $29 per cow made an average labor income of $245 per farm; the 37 farms with receipts ranging from $40 to $50 and averaging $46 per cow made an average labor income of $361; the 35 farms with average receipts of $56 per cow made an average labor income of $401; the 37 farms with average receipts of $65 per cow made an average labor income of $542; the 41 farms having average receipts of $79 per cow made an average labor income of $915; while the 24 farms with average receipts of $105 per cow made an average labor income of $1,053. Throughout this table the figures show a constant increase in the average labor income when the average receipts per cow increase. There was only a small variation in the different groups of the number of cows per farm.

This analysis suggests a very profitable line of improvement for farms of Lenawee County on which dairying is carried on to a greater or less extent. With one-fourth of the dairy farms in this area reporting returns of less than $50 per cow, the importance of keeping individual records for each cow and of eliminating the unprofitable becomes evident. It further suggest the possibilities for increasing the income by breeding up and systematically improving the entire dairy herd. The production per cow is one of the very essential factors in making dairying profitable.

CROPPING SYSTEMS.

Another factor of profitable farm management is the choice of a cropping system and the proper distribution of the crop area among the different crops. As previously stated, and as shown in Table III, on 300 owner and 153 tenant farms, corn occupies an average of 29.5 per cent of the total crop area of each farm; oats 17.5 per cent; wheat 14.9 per cent; barley 2 per cent; and hay 31.3 per cent. The tabulation of the data gathered on 300 owner-farms shows that in general on the more profitable of these farms corn occupies from 30 to 50 per cent of the total crop area, or an average of about 40 per cent; oats 1 to 20, or an average of about 10 per cent; wheat from 10 to 30, or an average of about 20 per cent; barley, roughly, from 1 to 10 per cent, and hay from 20 to 30 per cent. These results are significant. Consider, in the first place, their bearing on the corn crop.

Since 1880 the corn crop in Lenawee County has more than doubled in acreage. In spite of this and in spite of the fact that it is still increasing in acreage, the indications are that corn on the average farm has not yet reached the acreage it might well occupy. There is every indication that on the average farm the acreage of corn should be increased until this crop occupies anywhere from 30 to 50 per cent of the total crop area, according to the needs of the farm for feed, and distance necessary to haul in marketing the surplus of the crop. It is a significant fact in this connection that each year from 75 to 100 cars of corn are distributed to the farms of Lenawee County from Adrian alone. A material increase in the acreage of corn on the average farm seems indicated as one step toward placing these farms on a more profitable basis.

A further comparison of the figures presented shows that the total crop acreage devoted to oats (17.5 per cent) puts this crop well toward the upper limit of the acreage which it should occupy. As a source of cash income, the oat crop is relatively unimportant, but in this section oats are so valuable as a farm feed that it is still very important that a good acreage be devoted to this crop. The oat crop in many instances also is used as a means of getting a stand of clover.

The average crop acreage devoted to wheat (14.2 per cent) puts this crop a little below the average of the total crop acreage of the more profitable farms. Wheat is an important cash crop, and while at normal prices it is not always highly profitable from an acre basis, it is nevertheless essential to a well-balanced and diversified farm system in this region, especially on the heavier types of soil. Like the oat crop, wheat is of value to the farm system in that it affords a good means of getting a stand of clover and timothy for meadow and pasture. Under the conditions found normally in Lenawee County the combined acreage of wheat and oats should about equal that of the acreage of hay in the rotation.

Barley holds a minor position from the standpoint of the area as a whole and is of little consequence as a cash crop. The figures show, however, that barley is still important as a feed crop and is much in favor with some farmers.

The average acreage of hay (31.7 per cent) puts that crop well up toward the limit to which this crop may well be grown under the conditions now existing here. In any diversified farming region there are two important factors which tend to keep the acreage of hay from fluctuating materially. These are market prices, and the returns it is possible to get from feeding hay to live stock. Conditions which would materially affect either or both of these factors for a considerable period of time would cause a change in the acreage which should be devoted to the hay crop, but under the present conditions hay on the average farm of the region seems to have found its proper status.

CROP ROTATIONS.

There are several cropping systems in vogue in Lenawee County. Fixed rotations are the rule rather than the exception in this section. Some of these rotations do not meet present conditions, however, as well as might be desired, in that they do not provide for sufficient acreages of the more profitable crops.

The greater number of the farms studied follow a five-year rotation. The most popular rotation of this class is (1) corn, (2) oats, (3) wheat, (4 and 5) grass two years. The five-year rotation next in importance is as follows: (1) corn, (2) oats (or wheat or barley), (3, 4, and 5) grass three years. One encountered still less frequently is (1) corn, (2) corn, (3) oats, (4) wheat, (5) grass. This rotation is very desirable as it allows for two fields of corn rather than one, furnishes oats enough for feed, and perhaps a small surplus for sale, enough wheat for a substantial cash crop, and hay enough for the average farm. In many instances it might be well to extend this rotation into one of six years' duration by allowing the grass to remain two years before plowing it up. Where it is not desirable to grow wheat, this rotation might well be conducted as follows: (1) corn, (2) corn, (3) oats, (4 and 5) grass two years.

The principal six-year rotation encountered on the farms studied is (1) corn, (2) oats, (3) wheat, (4, 5 and 6) grass three years. A rotation encountered less frequently, but better suited to the conditions of the area, is (1) corn, (2) corn, (3) oats, (4) wheat, (5 and 6) grass two years. A modification of this system was found as follows: (1) corn, (2) corn, (3) oats, (4) wheat and barley, (5 and 6) grass two years. In this case wheat and barley of the fourth year occupy jointly the same field in whatever proportion the operator desires to meet the needs of his farm. The acreage of barley grown is usually governed by the need of this crop as feed for hogs, or in some instances, for dairy cows.

After the five and six year rotations, four-year rotations were most numerous, the most common of these being (1) corn, (2) oats, (or wheat or barley), (3 and 4) grass two years. After this in order of popularity, comes the following: (1) corn, (2) oats, (3) wheat, (4) grass. A very desirable four-year rotation, found less frequently, is (1) corn, (2) corn, (3) oats or wheat, (4) grass. In this rotation barley might be allowed to share a part of the oats or wheat field if this crop is needed on the farm.

The addition of alfalfa to the average cropping system of the section is very desirable generally, and since alfalfa can be depended upon to produce hay for several years, it is the custom to set apart a certain field of the farm for this crop, outside of the regular rotation. A rotation well adapted to the condition in the area and which is shown by the data collected to be a very profitable arrangement of crops on the average farm, is as follows:

First year	Corn.
Second year	Corn.
Third year	Oats and barley.
Fourth year	Wheat.
Fifth year	Hay.
Five years or more on a separate field	Alfalfa.

This rotation permits approximately 40 per cent of the rotation area to be in corn, which is the percentage indicated as most desirable in general in this section. Oats and barley together occupy about 20 per cent of the rotation area. These two crops, occupying the same field together, may be varied in acreage to suit the conditions of the individual farm. The wheat crop occupies about 20 per cent of the rotation area. Since this rotation provides for only 20 per cent of hay, whatever more is needed is supplied by the alfalfa crop. If this arrangement produces a surplus of hay, some of the grass of the fifth year may well be pastured or plowed under to improve the soil.

CASH CROPS.

In running a farm it is not always an easy matter to determine whether crops should be sold or not and, if sold, to what extent. On most farms there is generally more or less shifting in practice as regards the selling and the feeding of certain crops. This is especially noticeable in the relation between the price of corn and the price of hogs. If the price of hogs is high and that of corn relatively low, the greater part of the corn crop is fed, but if the opposite is true farmers in general are apt to sell off most of their hogs in rather poor condition and sell most of their corn crop as grain. Following the market in this manner is doubtless very often carried to extremes, and those who stick to the feeding of live stock continuously usually make more money in the long run than those who shift their practice in this respect from year to year. Nevertheless, the moderate selling of crops as a part of a general and diversified system of farming should not be discouraged.

Table VIII, page 15, under "Type of farming," indicates that of the 300 owner-farms studied in Lenawee County those receiving from 10 to even 40 per cent of their total receipts from the sale of crops were the more profitable. Tables were also constructed in this connection with a view to bringing out the most profitable percentage of total receipts from the sale of crops, and these indicate that under normal conditions and with the types of farming thus far developed here the greatest profit is derived when not more than 10 per cent of total receipts is derived from the sale of any one of the general farm crops. The only exception to this is in the case of wheat, which apparently may run as high as 20 per cent of the total crop acreage, and which might be increased considerably in case of high prices of wheat, such as during 1916–17.

SPECIAL CROPS.

There are several new crops which are either entering rapidly into the farming systems of the area or are beginning to attract attention. Of these the one of greatest importance and value to the section is alfalfa. There are two other crops which should be considered in connection with the agriculture of the county, though in only a limited way. These crops are soy beans and cowpeas.

ALFALFA.

Alfalfa is of comparatively recent introduction in this section, but already it has gained prominence on many of the best farms. Conditions in general are favorable for further developments, and more extensive seeding of this crop is taking place each year. There is not much tendency toward specializing on alfalfa to the extent of making it the most important enterprise of the farm. The indications are that this crop is gradually assuming a permanent place in the cropping systems of the section and as a rule it is not assuming undue prominence or interfering with the proper handling of the remainder of the farm crops. (See fig. 8.)

A reasonable acreage of alfalfa is very desirable on most farms of this section, but too great an acreage is not easily managed. One of the most important factors in determining a desirable acreage of alfalfa on a given farm is the labor schedule. The records taken in this area show that the average dates of harvesting the first cutting of alfalfa is from June 4 to 11. The early and more critical stages of the cultivation of corn come at the same time. As the acreage of alfalfa is increased the interference with the proper cultivation of the corn crop increases. Thus the corn crop becomes very largely the determining factor as to how great the acreage of alfalfa shall be. If the acreage in alfalfa is increased beyond moderate proportions, it will become advisable to reduce the acreage of corn accordingly, or means must be devised for securing extra labor to take care of the work at the time of the first cutting. It is the first cutting that is the greatest factor in this connection, as there is but little conflict in the labor of other crops when the second and third cuttings of alfalfa are done. On only two of the farms studied has alfalfa been made the dominating feature of the farm system. These have been discussed at some length on page 17 under "Special farms."

FIG. 8.—A good stand of alfalfa, Lenawee County, Mich.

On the whole, conditions are favorable to a much greater extension of the acreage of alfalfa in the area, especially on the heavier soil types. However, a number of details should receive closer attention. In a large number of fields the effects of poor drainage were clearly evident. There were numerous spots where the alfalfa had been winterkilled. These occurred alike on hill slopes and in depressions where the drainage was naturally poor or where seepage has kept the soil constantly saturated with an excess of water. A thorough system of tile drainage will prevent winterkilling to a very great extent, if not almost entirely. If it is not convenient to give the entire alfalfa field a thorough drainage system, it is at least highly desirable to drain the parts of the fields where the crop has been killed out. This should be done before existing fields are reseeded, or tile may be put in the parts of the field which have been killed out and these may be reseeded without molesting the stand in the remainder of the field.

The results which have been obtained with alfalfa in this area have been secured almost entirely without the use of lime or artificial inoculation. There is no doubt that both would be of considerable assistance in starting new fields and that they would add materially to the production of hay after the crop is well established. On farms where it has been difficult to get a stand of alfalfa, and especially on the sandy types of soil, it would be well to apply from one to three tons of ground limestone or marl per acre and work it well into the surface while preparing the seed bed. This general treatment has proven very effective on sandy lands in general in northern Indiana and southern Michigan.[1]

In most cases the seed either should be inoculated with artificial culture, or with sweet clover soil or soil from another alfalfa field scattered over the surface and harrowed in shortly before sowing the seed. (For full details see Farmers' Bulletin 704.)

Considering the fact that alfalfa, in general, is doing well in nearly all parts of the area surveyed, and that it has been established with little effort other than preparing the ground thoroughly and sowing the seed, it would seem that in this section this crop promises well for the future. A little more attention to details would go far toward insuring success. Tile drainage, lime, and artificial inoculation are the essential factors of success which are being neglected most. More attention should be paid to those factors, together with careful consideration of the most desirable acreage to meet the demands of the individual farm and at the same time not to interfere with the labor schedule of the farm in general and with the cultivation of the corn crop in particular.

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[1] United States Department of Agriculture Farmers' Bulletin 716, entitled, "Management of Sandy-land Farms in Northern Indiana and Southern Michigan."

SOY BEANS.

Apparently the soy bean crop has no special importance in the agriculture of the area, except in the more sandy sections or on lands where clover is grown with considerable difficulty. The area surveyed is made up principally of the heavier types of land, and the results of these investigations apply more especially to the heavy land conditions of Lenawee County and counties to the north, west, and southwest where these same conditions prevail. In these sections clover is grown with a high degree of success and alfalfa is very successfully grown on the farms where reasonable effort has been made. This leaves little to be expected from the growing of soy beans and really permits little demand for the crop in the agriculture of the section. The principal uses to which soy beans can be put in this section are that of a crop to be plowed under in a systematic plan of soil improvement, an extra crop to be grown for winter feed for hogs, and a catch crop sown in the corn at the last cultivation and pastured down by lambs during the first part of the feeding season. Soy beans may also be used to some extent as an emergency crop to supply hog pasture, but it apparently has no place of importance as a regular part of the cropping systems of the section.

COWPEAS.

As compared to soy beans, cowpeas as a farm crop are even less adapted to the agriculture of the area covered by this farm management study. The only place here where cowpeas can serve a purpose of any consequence is in the sandy sections. On the more sandy areas this crop can be grown to good advantage, and, together with soy beans, may to a great extent be used as a substitute for clover. Under these conditions cowpeas may be made valuable as a crop to be plowed under in the improvement of the soil. Another use which it may serve on these sandy areas is that of cow pasture—a practice which is carried out in other parts of southern Michigan. Aside from a few such general uses, this crop should not be considered in the area surveyed, especially not as a part of a regular and fixed rotation.

OWNER AND TENANT FARMS COMPARED.

Tenancy, though not abnormally developed, is nevertheless an important feature of the agriculture of Lenawee County. Of the 564 farm records taken, 300 were of owners, 90 were of owners who rented land additional and 16 of owners, generally of advanced years, who had curtailed their farm operations and were renting out a part of their land. There were 158 strictly tenant farms, 33 of which were cash rented, 120 half-share rented, and 5 one-third share rented. In all there were two and one-half times as many owner-farms as there were tenant farms. This probably represents about the true proportion of owners and tenants for the region as a whole, since the farms were visited and the records taken without discrimination in the area studied.

TABLE XVI.—*Average area, capital, receipts, expenses, and profits of owner-farms as compared with tenant farms, Lenawee County, Mich.*

	Owner-farms.			Tenant-farms.					
				Tenant.			Landlord.		
	Owner.	Owner renting additional land.	Part of land rented out.	Cash rent basis.	One-half share rent basis.	One-third share rent basis.	Cash rent basis.	One-half share rent basis.	One-third share rent basis.
Number of farms	300	90	16	33	120	5	33	120	5
Average area, acres	104	120	92	102	135	159	....	....	....
Average capital	$11,756	$9,692	$9,090	$1,765	$1,506	$582	$9,061	$13,015	$16,406
Average receipts	$1,578	$1,718	$1,111	$1,362	$966	$861	$279	$859	$1,577
Average expenses	$510	$764	$385	$623	$326	$485	$30	$129	$507
Average farm income	$1,068	$954	$726	$739	$640	$376	$249	$730	$1,079
Per cent on investment	5.8	5.9	4.9	20.3	16.1	....	2.7	5.6	6.5
Interest on investment at 5 per cent	$587	$485	$454	$88	$75	$29	....	....	....
Average labor income	$481	$469	$272	$651	$564	$347	....	....	....

It will be observed in Table XVI that the average size of the 300 owner-farms was 104 acres, the owner with additional rented land 120, and the owners with part of the land rented out 92; whereas the cash tenant farms were 102, one-half share 135, and one-third share 159 acres, respectively. Here it will be noted that the principal group of tenant farms, those rented on the half-share plan, are on the average considerably larger than the owner-farms, and that the small number of farms rented for one-third share average still larger. This last-named class is of rather peculiar type, since the owner, in addition to working on the farm himself, generally furnishes all equipment and most of the live stock, giving one-third of the farm income and a credit of one-third of the increase in live stock to the renter for his labor. Only five such farms were found in the four townships studied.

The 300 strictly owner-farms had an average capital of $11,756, the 90 owners with additional rented land, $9,692, and the 16 owners with part of the land rented out had an average capital of $9,090. On the 33 cash-tenant farms the tenants had an average investment of $1,765, and their respective landlords had an average investment of $9,061; the 120 half-share tenants had an average investment of $1,506, and their landlords had an average capital of $13,015; and the five one-third share tenants had the very low average capital of $582, whereas their landlords had an average investment of $16,406.

In regard to farm income, which is the gross receipts minus expenses, the tenants compare favorably with the landlords but fall slightly lower than the 300 owners and the 90 owners with additional rented land. The average farm income of the 300 owners was $1,068; that of the 90 owners with additional rented land, $954; and that of the 16 owners with a part of their land rented out was $726. The average farm income of the 33 cash tenants was $739, and that of their landlords, $249; the average farm income of the 120 one-half share tenants was $640, and that of their respective landlords was $730; whereas the average farm income of the five one-third share tenants was $376, and that of their landlords, $1,070. It should be observed in this connection that the landlords' farm income on the one-third share farms ($1,070) includes pay for whatever work the landlord himself has done on the farm, and taking into account the difference in capital, the landlord's income naturally should be somewhat higher by this plan of operation than that of the tenant.

After subtracting the average estimated values of the labor of owners and of tenants from the farm income, the owners have left as interest on their investment 5.8 per cent; the owners with additional rented land, 5.9 per cent; the owners with part of their land rented out, 4.9 per cent. The average per cent on the small investments of the tenants run much higher. The cash tenants made an average of 20.3 per cent, and the one-half share tenants made an average of 16.1 per cent. It must be remembered, however, that these men were limited in the investment that could be handled economically in the form of working capital. The percentage returns must, therefore, be much higher than that for the entire capital of the farm if these men are to receive a fair return for their labor. The 33 landlords renting their farms for cash received an average of 2.7 per cent, and the 5 landlords renting on the one-third share plan received an average of 6.5 per cent on their respective investments. It would seem that the per cent received by the cash-renting landlords (2.7) is rather low, but some consideration should be given to the certainty of income under this plan.

It will be seen that the average labor income on the owner-farms was $481; of the owners with additional rented land, $469; and of the owners with part of the land rented out was $272; while that of the cash tenants was $651; of the 120 half-share tenants, $564; and of the one-third tenants, $347.

Tenants naturally look forward to the time when they shall be owners and gain that coveted feeling of independence which comes with the ownership of land. Conditions vary greatly in different sections with respect to tenancy, and it is not always an easy matter to say when and under what circumstances the tenant should become an owner. Generally there is a decided inclination, however, to ignore the possibilities of renting and to hasten unduly into ownership. It is highly advisable to make sure that sufficient capital is available, so that this change may be made without assuming too great a financial obligation. Neglect to do this often results in hardship and sometimes in financial difficulties which are hard to overcome. When to give up renting and become an owner, whether a man with small capital should buy a small farm or rent one of greater acreage until he has accumulated sufficient capital to acquire a farm of suitable size, are often serious questions. The data gathered in this connection in Lenawee County show what is actually taking place in that region.

TABLE XVII.—*Relation of tenure, with a given amount of capital, to income, Lenawee County, Mich.*

Operator's capital.	Number of farms.		Acres of land per farm.		Average farm income.		Average labor income.	
	Working owners.	Tenants.	Working owners.	Tenants.	Working owners.	Tenants.	Working owners.	Tenants.
$1,000 or less	....	35	....	81	....	$413	....	$376
$1,001 to $2,000	4	88	29	126	$296	622	$210	548
$2,001 to $3,000	5	23	38	182	375	971	244	852
$3,001 to $5,000	21	5	42	231	392	1,266	187	1,094
$5,001 to $7,000	34	2	61	183	655	1,648	351	1,366
$7,001 to $9,000	55	....	77	....	689	....	289	....
$9,001 to $11,000	54	....	89	....	989	....	485	....
$11,001 to $14,000	42	....	104	....	1,143	....	525	....
$14,001 to $17,000	27	....	130	....	1,185	....	420	....
$17,001 to $25,000	42	....	171	....	1,670	....	667	....
Over $25,000	13	....	282	....	3,427	....	1,728	....
All farms	3,000	153	104	128	1,069	661	481	583

Table XVII shows that of all the farms surveyed there were no owners operating with $1,000 or less capital. There were 35 operated by tenants each of whom had not more than $1,000 at his disposal. The average area of the farms operated by these tenants was 81 acres, and the farm income averaged $413 per farm. Allowing 5 per cent interest on the capital, the average tenant made a labor income of $376. This shows that, in general, it is possible in this section to rent and manage a farm of fairly good acreage when a capital approximating $1,000 has been accumulated, and that in addition to making a reasonable rate of interest on this capital it is possible to realize a labor income slightly above the wage of a hired hand, which in this region averages about $360 per year.

There were only four owner-farms which were operated with capital of from $1,001 to $2,000, whereas there were 88 tenant farms in the same class. It will be noted that there is a material increase in the number of tenants whose capital falls between these limits as compared with those having $1,000 or less. It should be observed also that the average acreage of the owner-farms is very small, only 29 acres, while that of the tenant farms is 126 acres. The owners in this class made an average total farm income of $296, while the renter made a farm income of $622. After taking out 5 per cent interest on the investment in each case the owners are left an average labor income of $210, the renters $548. This shows that under current conditions it is still much more desirable to rent than to buy until the capital available for investment has reached $2,000 or more.

In the third class, the operator having capital ranging from $2,001 to $3,000, there were 5 owners and 23 tenants. The average area of the owner-farms was still small, being only 38 acres, whereas the average area of the farms operated by renters was 182 acres. A comparison of incomes shows still greater differences. The owners made an average total farm income of $375, as compared with $971 made by the tenants, and an average labor income of $244 as compared with $852 made by the tenants.

In the fourth division, those having investments of $3,001 to $5,000, there are only 5 tenants as compared with 24 owners, and in the next class, with investments of $5,001 to $7,000, only 2 renters were found, as compared with 34 owners. No renters were found with an operating capital of more than $7,000.

The average farm income for five tenants in the group with investments of from $3,001 to $5,000 was $1,266, and that of the two tenants in the group with investments from $5,001 to $7,000 was $1,648. It will be noted that the average farm income of the owners does not approach these amounts until the group is reached in which the owners have investments ranging from $17,001 to $25,000, and farms average 171 acres in area, or approximately the area of the larger rented farms.

Farm management surveys have, in general, shown that just as soon as the tenant farmers have accumulated sufficient capital to enable them to make a first payment on a farm of sufficient size to permit a satisfactory standard of living, the great majority of them pass over into the owner class. In Table XVII it is seen that when the average tenant in the region here studied has saved about $5,000, thus becoming able to possess a farm which will produce a farm income of about $400, he prefers to become an owner, despite the fact that as a tenant he could have an income practically three times as great. In this area no farmer remained a tenant after he had accumulated more than $7,000 capital.

There are two general reasons for this. In the first place, the adequate utilization by the tenant of a large operating capital requires a very large area of land, in many cases necessitating a magnitude of business that is beyond the managerial ability of the average individual. The table indicates, however, that the man of exceptional ability who can manage a large property with a high degree of efficiency could continue to do better financially as a tenant than as an owner, because of the greatly increased acreage which his capital would enable him to utilize.

Perhaps more important considerations that influence farmers to become owners as soon as it is possible to do so on a satisfactory basis are those relating to the very numerous advantages arising from ownership. The sense of security and independence which ownership gives is a valuable consideration. The feeling of satisfaction in owning a home is undoubtedly one of the factors that influence many farmers to buy land. Finally, the greater independence of the owner as compared with the tenant who is in the nature of things more or less subject to dictation from the farm owner, and the fact that the owner is never under the necessity of moving from one farm to another because of disagreements with his landlord, seem to justify whatever financial sacrifice may be necessary in changing from the status of tenant to that of owner.

From the standpoint of the public welfare, it is fortunate that the tendencies just mentioned prevail so generally. As a rule, tenant farmers are not a permanent part of the local citizenship, and are not so much interested as owners in the maintenance of schools, churches, and roads.

The figures of the table, however, indicate quite clearly that in this section it is a mistake for the young man with small capital to attempt to become an owner before his accumulated capital renders it possible for him to make a satisfactory first payment on a farm of considerable size. Even where the first payment required is only a small proportion of the total value of the farm, interest on deferred payments consumes so large a proportion of the farm income that unless the business is one of considerable magnitude there is not enough left to permit a satisfactory standard of living. It is, however, desirable that the tenant, when he has accumulated sufficient capital to become an owner on a proper basis, should purchase a farm.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 695

Contribution from the Bureau of Crop Estimates.
LEON M. ESTABROOK, Chief.

Washington, D. C. ▼ October 16, 1918

POTATOES: ACREAGE, PRODUCTION, FOREIGN TRADE, SUPPLY, AND CONSUMPTION.

By GEORGE K. HOLMES, *Division of Crop Records.*

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SOURCES, SCOPE, AND LIMITATIONS.

Intelligent use of the statistical matter contained in this bulletin depends on observing these explanations concerning its sources, scope, and limitations:

AREA.—Of production: Contiguous United States. Of foreign trade: Contiguous United States and, beginning with their inclusion in national trade, Alaska, Hawaii, and Porto Rico. Commodities received by contiguous United States from Alaska, beginning July 1, 1902, ceased to be included in technical "imports" and became "shipments" from the Alaska customs district, and so with Hawaii for 1901 and Porto Rico for 1900. Similarly, "domestic exports" from contiguous United States to these Possessions became "shipments" in the years mentioned. There was a change from external

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NOTE.—This bulletin contains information which is of interest to the public at large as well as to those who are specially interested in potato production, trade, and consumption.

to internal trade in the accounting. The shipments of potatoes between these possessions and contiguous United States if any, are too small to affect the results appreciably as applicable to contiguous United States, and hence are not added to imports or domestic exports, as the case may be, beginning with the years mentioned, to determine the full movement into and from contiguous United States. The Philippine Islands have always been treated as a foreign country in the foreign trade statistics of the United States.

Year.—Of production: Year of planting, growth, and harvest. Of foreign trade: Fiscal year beginning July 1. Hence, the year of production is approximately related to the year of foreign trade, of supply, and of consumption.

Population.—Confined to contiguous United States, June 1 estimates for noncensus years before 1910, and also for 1910 and later years, the census date for 1910 being April 15 instead of June 1 for many preceding censuses; supplied by Bureau of the Census.

Acreage.—Bureau of the Census: 1889 and later decennial census production years. For 1869 and 1879, census production divided by production per acre estimated by Bureau of Crop Estimates. Bureau of Crop Estimates: Estimates for noncensus years; for 1890–98 and 1900–8, new estimates of acreage made in 1917.

Production.—Bureau of the Census: 1849 and later decennial census production years to 1879. Bureau of Crop Estimates: Estimates for noncensus years; for census years 1889 and later, census acreage multiplied by yield per acre.

Production per acre.—Bureau of Crop Estimates: Estimates by States weighted to compute United States average.

Farm price per bushel.—Estimates by States by Bureau of Crop Estimates multiplied into State production, and total United States value divided by total United States production, for all years, including decennial census production years. For date of December 1.

Total farm value of production.—Farm price per bushel, estimated by States by Bureau of Crop Estimates, multiplied into State production; total value of all States for all years, including decennial census production years.

Imports.—Gross imports to year beginning July 1, 1910; imports for consumption for later years; Bureau of Foreign and Domestic Commerce. Years begin July 1.

Supply.—From the formula of production plus gross imports to the year beginning in 1910, and plus imports for consumption for 1911 and later years. Carry-over does not enter into the problem for the reason that potatoes are not a carry-over crop.

Domestic exports.—Goods produced or manufactured in this country from either domestic or imported raw materials; Bureau of Foreign and Domestic Commerce. Years begin July 1.

VALUES OF FOREIGN TRADE.—The values of imported articles subject to ad valorem duties are defined by the Act of Congress of June 10, 1890, as—

> The actual market value or wholesale price of such merchandise as bought and sold in usual wholesale quantities at the time of exportation to the United States in the principal markets of the country from whence imported, and in the condition in which such merchandise is there bought for exportation to the United States or consigned to the United States for sale, including the value of all cartons, cases, crates, boxes, sacks, and coverings of any kind, and all other costs, charges, and expenses incident to placing the merchandise in condition ready for shipment to the United States.

The value of all other imports, whether subject to specific duty or free of duty, is determined also according to the law just quoted. The customs duty, if any, is not reckoned as a part of the import value. The value of domestic exports is their declared value at the time of exportation in the ports of the United States whence they are exported, which the law requires to be stated under oath, with penalty for misstatement. Tare included.

GOLD.—All values and prices have been reduced to gold for 1861–1878.

POTENTIAL CONSUMPTION.—From the formula of production plus gross imports to the year beginning in 1910, and plus imports for consumption for 1911 and later years, minus domestic exports. The result stands closely for actual consumption in each year. No account is taken of stocks at beginning and end of year; potatoes are not a carry-over crop. The computed consumption includes potatoes used for seed, for live-stock feeding, and for starch manufacture, as well as for human food and the quantity lost in waste.

AVERAGES OF 10-YEAR PERIODS.—If the average is derived from one column, the years represented are added and the total is divided by the number of years represented. A difference between two columns is for the years represented in both columns.

If an average of averages or of percentages is computed, the years that are represented in both of the two base columns are added and one total is divided by the other, as indicated; except that production per acre and per capita production per acre are unweighted means.

Every average for less than 10 years is preceded by a* and that is preceded by a figure indicating the number of years represented.

FOOD HABITS.

So great have been the variety and abundance of foods in this country and the dominance of sectional food habits that potatoes have never reached a prominence in the national diotary that they occupy in some other countries. Among the different groups of States the dietary importance of this tuber varies enormously. In much of the South it is greatly subordinate to sweet potatoes, yams, rice, hominy, and corn bread and similar preparations of corn meal, while, at the other extreme, in many States of the North, it is customarily served at breakfast and dinner and perhaps infrequently at the third meal of the day.

The potato is subordinate to food habits, and these are largely formed in childhood. Great increase or diminution in its consumption as food is influenced by low or high price, by abundance or scarcity, and by the relative standing of substitute foods. The potato eaters of this country are accustomed to a full potato consumption according to their desires, and this is not large, as a per capita average for the whole country, when comparison is made with prominent potato-consuming countries. Under normal conditions, there are usually so many other things to eat in generous supply that the practical upper limit of potato consumption is easily reached. On the other hand, in a year of short supply and high price of potatoes, substitutes are accepted, but reluctantly so. Following the underproduction of potatoes in 1916, a retail price of 75 cents to $1 a peck caused many a family to substitute rice, corn meal, and hominy.

ACREAGE.

The acreage of the potato crop in this country, as reported by the decennial censuses, is for farms and does not include the numerous gardens that produce potatoes off farms. The actual acreage from year to year is the result of the individual opinions of the farmers who produce potatoes with regard to the prospective total demand and price during the coming year, and in practice there is likely to be less miscalculation concerning acreage than there is concerning the various causes of high or low production per acre. Potentially the usual potato acreage of this country could be increased enormously.

The acreage of the potato crop was first determined by estimate by the Bureau of Crop Estimates for 1866 to be somewhat over 1,000,000 acres; in 1869 the census production was divided by the average production per acre estimated by this bureau and the computed acreage was 1,309,000 acres; similarly in 1879 the computed acreage was 1,713,000 acres. The first acreage determined by census enumeration was for 1889, and was found to be 2,601,000 acres, and the number of acres increased to 3,669,000 in the census year 1909, followed by small increase in later years, except that 4,390,000 acres were harvested in 1917, and that in 1916 the estimate of the acreage of this crop was 3,565,000 acres, or considerably below the acreage of the preceding seven years.

During the nine years, 1866–1874, the average potato acreage was 1,243,000 acres, and the acreage increased during each subsequent 10-year period until the average for 1905–1914 reached 3,541,000 acres, an increase of nearly 200 per cent in 40 years.

PRODUCTION.

QUANTITY.

The first census report of potato production was 65,798,000 bushels raised in 1849; by 1859 the crop had become 111,100,000 bushels. The yield was 201,200,000 bushels in 1889, and 394,553,000 bushels in 1909, a production that was subsequently exceeded only by the estimated production of 420,647,000 bushels in 1912, 409,921,000 bushels in 1914, and 442,536,000 bushels in 1917.

Since 1899 the years of low potato production were 1901 with 198,626,000 bushels, 1911 with 292,737,000 bushels, and 1916 with 286,953,000 bushels. The average yearly production of the 10 years, 1905–1914, was 343,394,000 bushels.

BY GEOGRAPHIC DIVISIONS.

The geographic distribution of the potato crop among the different sections of the country in each census year and in 1912 and 1916, years of high and low production, has undergone interesting changes. If the crop of each geographic division is represented by a percentage of the total crop of the United States for each year, it appears that the New England crop declined relatively from 19.2 per cent of the national production in 1859 to 6.2 per cent in 1889; this latter percentage was nearly doubled in 1916, and there are indications that New England is tending toward a larger fraction of the national production.

On the other hand, the Middle Atlantic States have declined from 38.1 per cent of the national production in 1859 to 18.1 per cent in 1916. From 1869 to 1912 the East North Central States maintained approximately the same relative position in potato production, or about 28 to 35 per cent of the entire production, but the West North Central States increased their relative production from 7 per cent in 1859 to 26.6 per cent in 1889, followed by decline on the whole to 17.9 per cent in 1916.

Marked relative increase of potato production is found in the South Atlantic States, where the percentage remained nearly constant at about 4 until 1899, after which it increased strongly to 11 per cent in 1916. Tendency to increase is found also in the East South Central States from 1899 to 1916, although the fraction is comparatively small, ranging from 1.8 per cent in 1899 to 3.4 per cent in 1916, or for the latter year about the same percentage as for 1859. In the West South Central States also the percentage is small, but it has increased from 0.9 per cent in 1859 to 2.5 per cent in 1916.

West of the Great Plains relative potato production has conspicuously increased. In the Mountain region relative production has been from almost nothing in 1859 to 8.9 per cent in 1916, and in the

Pacific States the increase during the same period has been from 2 to 10.1 per cent.

In 1916 the South produced 16.9 per cent of the national crop of potatoes, the Mountain and Pacific States 19 per cent, New England and the Middle Atlantic States 30.2 per cent, and the North Central States 33.9 per cent.

As has been otherwise stated, the South produced about one-sixth of the national crop of potatoes in 1916, and this crop was very largely of early potatoes. Two characteristic crops of potatoes are produced in this country, the early and late crops, and the southern crop, largely of early potatoes, is mostly for consumption in the North at a time when the late crop of the preceding year has been nearly all consumed and the oncoming new crop of early potatoes sells for comparatively high prices.

PER ACRE.

The Bureau of Crop Estimates first determined, by estimate, the average yield per acre of the potato crop of this country beginning with 1866. From that year to the latest year the high averages are 113.4 bushels per acre in 1912, 111.1 bushels in 1904, 110.5 bushels in 1875 and 1914, 109.5 bushels in 1869, 107.5 bushels in 1909, 102.2 bushels in 1906, and 100.8 bushels in 1917. On the other hand, the years of low average production per acre are 1881 with 53.5 bushels, 1890 with 56.7 bushels, 1887 with 56.9 bushels, 1892 with 62.1 bushels, 1894 with 63.6 bushels, 1901 with 66.3 bushels, 1897 with 67.9 bushels, and 1878 with 69.9 bushels. The yield per acre in 1916 was 80.5 bushels, a low average for recent years which combined with an acreage below the usual to produce a deficient crop.

During the 9-year period 1866–1874 the average yearly yield of potatoes per acre was 91 bushels, and the average markedly declined to 71.3 bushels in the 10-year period 1885–1894. Perceptible recovery was made in the following 10-year period, and much larger recovery, rising to a new high-water mark, was reached in the 10-year period 1905–1914 with its average yield of 97 bushels per acre. In 20 years the productivity of the average potato acre has increased 36 per cent. This increase is due to various causes and among these are greater specialization of production, more intensive treatment, and higher fertility of the soil.

Notwithstanding great improvement in recent years, the average yield of potatoes per acre in the United States is low in comparison with the averages of prominent potato-producing countries in Europe. For the 10 years 1900–1909 the average production of Germany is 200 bushels per acre; of the United Kingdom, 193.8 bushels; of Austria, 151.1 bushels; of France, 133.8 bushels; of Hungary, 118.7 bushels; and of European Russia, 99.9 bushels; while during the same period the United States averaged 91.4 bushels.

PER CAPITA.

For the crop year beginning in 1849 the per capita production of potatoes was 2.9 bushels, for 1859 it was 3.6 bushels, for the 10-year period 1885–1894 the yearly average was 2.9 bushels, or lower than that of any other period. The average was 3.45 bushels in the following 10-year period, and increased in the next 10-year period, 1905–1914, to 3.8 bushels per capita.

While total potato production per capita has increased since the 10-year period 1885–1894, the production per acre compared with population has slightly declined during the same time. Per 1,000,000 of population the production of potatoes per acre was 1.07 bushels in 1905–1914, and 1.15 bushels in 1895–1904 and 1885–1894. In former years the yield of potatoes per acre per 1,000,000 of the population was much higher and amounted to 1.72 bushels in 1875–1884, and 2.34 bushels in 1866–1874. Increase of productivity per capita per acre did not keep pace with increase of population from 1866–1874 to 1905–1914. The gain of production per capita in recent years has been more because of increased total acreage than because of increased production per acre.

VALUE OF CROP.

PRICE PER BUSHEL.

The record of the average price per bushel received by farmers for potatoes extends back to 1866, when the estimate for the United States was first made by this bureau. Great variations are found in the average annual prices since that time, and by far the highest price was reached for the crop of 1916, $1.46 per bushel. A price as high as 97 cents per bushel was reached for the crop of 1917, 91 cents for 1881, 80 cents for 1911, and 76 cents for 1901. On the contrary, prices have gone as low as 26 cents per bushel for 1895, 29 cents for 1896, 34 cents for 1875, and 35 cents for 1889.

Among the 10-year periods the highest average price per bushel of potatoes at the farm is for the period 1905–1914, when it was 59.1 cents per bushel. Proceeding backward in time, the price was lower in each preceding 10-year period until the price of 49.6 cents per bushel is found in 1875–1884. During the 9 years preceding that period the average was 56.6 cents per bushel, or a little under the average of the latest 10-year period.

TOTAL VALUE OF CROP.

The first estimate of the value of the farmers' potato crop was $50,723,000 for 1866. The total steadily increased to $99,291,000 for 1881, followed by a period of depression in total value with sudden recovery to $113,291,000 for 1890, the highest amount to that year. The next year to register high-water mark was 1901, the total value for which was $151,602,000; by 1908 the total had reached $210,618,000, and the total for 1915 was $221,992,000; 1916 witnessed an enormous increase in total value, for which year the estimate is $419,333,000, and this amount was much exceeded by $543,865,000 in 1917.

A strong tendency to increase from one 10-year period to the next is in evidence. The average total value of the farm potato crop for 1866–1874 was $63,799,000; for 1895–1904 it was $117,012,000; and during the following 10 years the average greatly increased to $202,855,000.

AVERAGE VALUE PER ACRE.

Upon relating the total value of the potato crop to the total acreage and computing the average value per acre, it appears that from the period 1866–1874 to 1885–1894 the average declined from $51.34 to $35.98. Then followed the somewhat higher average of $39.03 per acre for 1895–1904 and the remarkable increase of 1905–1914 resulting in an average of $57.28 per acre.

PERCENTAGE OF SUPPLY.

Production may now be viewed in relation to the national supply of potatoes, the understanding of the word "supply" being the entire quantity of potatoes produced in this country and received from other countries as imports. This supply is diminished by the exports of the domestic crop, but if there were no domestic exports the supply would be equal to the consumption. So small relatively are the imports of potatoes that the production has been from 98.4 to 99.8 per cent of the supply in 10-year periods; and these percentages approximately represent the range for value, that is, the percentage that the value of the crop is of the value of the supply.

IMPORTS.

QUANTITY RECEIVED.

Potatoes do not occupy a place of perceptible importance in the import trade of this country, except in a small degree in years when the production is deficient. As before stated, the production of potatoes in the United States is usually approximately the consumption, but let the production fall perceptibly below the customary consumption and imports begin to arrive from countries whose export trade is attracted by the higher prices of this country. So it has happened, for instance in the fiscal year beginning July 1, 1876, a year of low production, that the imports of potatoes, which had previously been relatively very small, suddenly amounted to 3,206,000 bushels; again in 1881, another year of low production. the imports reached 8,790,000 bushels; the next year of low production, 1887, was a year of imports amounting to 8,260,000 bushels; again in the similar year 1901 the imports were 7,656,000 bushels; and in 1908 they were 8,384,000 bushels. The largest amount of imported potatoes ever received by this country in one year was in 1911, when the quantity reached 13,729,000 bushels, and that was a year of large deficiency.

The annual averages presented by periods of years do not reach half a million bushels before the period 1875–1884, when the average yearly imports were 2,158,000 bushels. In the next 10-year period the average was 3,018,000 bushels, followed by 1,401,000 bushels in 1895–1904, and by 2,946,000 bushels in 1905–1914.

In a year of large imports the bulk of them is consigned from the United Kingdom, but in other years, when the import movement is relatively small, the larger fractions of the imports are usually from Canada and Bermuda, with Germany perhaps third in order, and Mexico and the Netherlands following.

VALUE OF IMPORTS.

The average annual value of the imported potatoes was $1,506,000 in the period 1905–1914, and this average was not previously equaled in any 10-year period. Previous to 1875–1884 the average was much below $1,000,000.

The values of imports are the values of the goods in foreign countries and do not include the costs of transportation from the foreign point of shipment to this couutry, nor the import duty of this country, if any.

The computed average import value of imported potatoes per bushel reached as high a figure as 61 cents for 1865–1874, and declined to 44.7 cents per bushel for 1885–1894, after which there was an increase to 51.1 cents per bushel in 1905–1914.

PERCENTAGE OF PRODUCTION.

The imports of potatoes as a percentage of potato production in this country have never exceeded 1.65 per cent of the crop, as an annual average for any 10-year period, this average being for 1885–1894. The lowest period average, 0.22 per cent, is found for 1866–1874. For the 10 years, 1905–1914, the imports were 0.86 per cent of the production. The percentages for value do not differ materially from those for quantity of potato imports.

PERCENTAGE OF THE SUPPLY.

Potato production and supply being so nearly the same, the imports of potatoes are related to the supply quite the same as they are to the production. The imports of the 10-year period 1905–1914 were 0.85 per cent of the supply. The largest ratio for any period, 1.62 per cent, is for 1885–1894, and the smallest ratio, 0.22 per cent, is for 1866–1874. The corresponding percentages for value are not materially different.

SUPPLY.

QUANTITY OF POTATOES.

As a total of potato production and imports, the supply of potatoes in this country increased, with various recessions, from 111,100,000 bushels in 1859 to 208,590,000 bushels in 1883, to 352,449,000 bushels in 1904, and to 420,982,000 bushels in 1912, the largest supply of potatoes ever in the possession of this country, except in 1917. The supply of 1913 was 335,171,000 bushels; of 1914, 410,191,000 bushels; and of 1915, 359,930,000 bushels.

As indicated by 10-year averages, the supply of potatoes has steadily increased until the average annual supply of the 10-year period 1905–1914, 346,340,000 bushels, was reached. This is a large increase over the average of the preceding 10 years, 262,625,000 bushels. The average for the 9 years, 1866–1874, was 113,055,000 bushels.

PER CAPITA.

The per capita supply of potatoes in this country was 2.92 bushels for 1849. For the 9 years, 1866–1874, the annual average was 2.89 bushels; during the next period, 1875–1884, the average was 3.27 bushels; and during the next two 10-year periods it was 2.99 and 3.47 bushels. The largest average for a period is 3.79 bushels per capita for 1905–1914.

VALUE OF THE SUPPLY.

The value of the potato supply in this country is first known for the year beginning in the year 1866, for which it was $50,810,000. By 1890 the value had risen to $116,089,000, and by 1908 it had risen to $214,295,000. The largest value is for 1916. For 1914 it was $199,734,000, for 1915, $222,324,000, and for 1916, $424,035,000.

DOMESTIC EXPORTS.

QUANTITY.

The exports of domestic potatoes are not subject to the wide range found in the case of imports. These exports did not reach 1,000,000 bushels until 1904, nor 2,000,000 bushels until 1910. By reason of the European war, the exports of domestic potatoes amounted to 3,135,000 bushels in the fiscal year beginning in 1914, to 4,018,000 bushels in 1915, and 2,489,000 bushels in 1916.

Previous to the war, in recent years more than one-half of the exports of domestic potatoes have been shipped to Cuba, about one-seventh to one-fifth to Canada, about one-tenth to Panama, and 6 to 8 per cent to Mexico.

PER CAPITA EXPORTS.

As may be inferred from the total amount, the per capita exports of domestic potatoes are represented by exceedingly small ratios. These hardly equal 0.01 per cent in the 10-year periods previous to 1905–1914, but for this period the ratio is 0.017 per cent.

VALUE OF EXPORTS.

The exports of domestic potatoes did not reach the value of $1,000,000 previous to 1906, nor the total of $2,000,000 previous to 1914, for which year the amount is $2,346,000. In the following year the value of exports of domestic potatoes reached the comparatively high amount of $3,486,000 and in 1916 the high value of $3,514,000 was reached.

From an export value of $99,000 in 1849, the exports of domestic potatoes rose to a value of $525,000 as an average for 1895–1904, and an average of $1,298,000 for 1905–1914.

From 1850 to 1914 the period averages of the value of exports of domestic potatoes range from 70.6 cents to 80.7 cents per bushel; for 1849 the average was 63.8 cents per bushel.

PERCENTAGE OF PRODUCTION.

Exports of domestic potatoes as a percentage of production present an obscure appearance. During no year has the fraction been as great as 1 per cent of the production except for 1916, when it was 1.12 per cent. The average for the 10-year period 1905–1914 was 0.47 per cent, and this was the average for the period 1866–1874. During the intermediate periods the fractions range from 0.28 to 0.36 per cent of the production. The percentages that the values of the domestic exports are of the values of the production do not differ materially from those representing quantities.

PERCENTAGE OF THE SUPPLY.

The potato supply is so nearly the same as the production that the exports of domestic potatoes are represented by percentages of the supply that are very nearly the same as the percentages of production. For the 10-year period 1905–1914 the exports of domestic potatoes were 0.46 per cent of the supply, a larger percentage than for any period subsequent to 1866–1874.

PERCENTAGE OF CONSUMPTION.

Potato consumption as well as supply is nearly the same as production, and consequently the exports of domestic potatoes have about the same fraction of consumption as they do of production. In the period 1905–1914 the average fraction of the consumption represented by the domestic exports is 0.5 per cent, a figure that is not exceeded for any period.

FOREIGN TRADE SURPLUS.

QUANTITY.

Previous to 1895 the imports of potatoes more generally exceeded the exports of domestic potatoes than they were exceeded by them, but subsequent to the year mentioned the more frequent fact is an excess of domestic exports over imports of potatoes. These remarks apply in a consideration of the separate years, but in a consideration of periods of years the imports exceed the domestic exports for every group except 1866–1874. The reason why the character of the individual years in later time is contradicted by the character of the later groups of years is found in the comparatively large imports of a few years when the production was deficient. The more common fact since 1895 is that the United States is a surplus country in potato production, and yet this country never had a surplus of potatoes amounting to 1,000,000 bushels in any year previous to 1906. For that year the surplus was 1,354,000 bushels; for 1910 the surplus was 2,165,000 bushels; for 1914 it was 2,866,000 bushels, and for 1915 it was 3,809,000 bushels, the highest amount ever reached. On the other hand, the excess of imports has run as high as 12,492,000 bushels in 1911, and amounted to more than 7,000,000 bushels in each of the years 1901 and 1908.

The surplus of foreign trade movement of potatoes, whether surplus imports or surplus domestic exports, makes a small ratio to population, in no case amounting to as much as one-tenth of 1 bushel except in 1881, when the ratio of surplus imports was 0.163 of 1 bushel, and in 1887 and 1911, with the same ratio, 0.133 of 1 bushel. These were years of extraordinary potato imports on account of deficient production.

VALUE OF SURPLUS.

The value of the surplus imports of potatoes over the domestic exports, found in every group of years except 1865–1874, in no instance reaches an amount higher than $950,000, the average for 1885–1894. The average value for 1895–1904 was $160,000, and for 1905–1914 it was $208,000.

PERCENTAGE OF PRODUCTION.

In no year does the quantity of the surplus exports of domestic potatoes over the imports amount to as much as 1 per cent of the production, except 1.06 per cent in 1915, and in no 10-year period is there a surplus of domestic exports except in 1866–1874, for which period the surplus is 0.24 per cent of the production.

The surplus imports of potatoes have run as high as 7.68 per cent of the production, this figure being for 1881; but usually the percentage has been below 1. For the 10-year groups of years the surplus imports as a percentage of the production range from 0.25 per cent for 1895-1904 to 1.36 per cent for 1885–1894. The value of the surplus imports of potatoes bears about the same relationship to the value of the production as the quantity of the surplus imports does to the quantity of the production, whether the subject be considered by groups of 10 years or by years separately.

PERCENTAGE OF CONSUMPTION.

The surplus imports of potatoes have been as high as 7.13 per cent of the consumption, in 1881, and no other year has as high a percentage, but often the percentage is less than 1. All of the 10-year periods except 1866–1874 are represented by a surplus of imports of potatoes, with fractions of consumption in no case higher than 1.3 per cent for 1885–1894.

The surplus exports of domestic potatoes in years when this fact is found have always been less than 1 per cent of the consumption, except 1.07 in 1915.

CONSUMPTION.

QUANTITY.

In 1849 this country consumed 65,815,000 bushels of potatoes. Fifty years ago the yearly consumption of potatoes was about 100,000,000 bushels. During the 9 years 1866–1874 the yearly consumption averaged 112,522,000 bushels. The annual average increased to 261,889,000 bushels during the 10-year period 1895–1904, after which there was a great increase to 344,733,000 bushels during 1905–1914. In 1915 the consumption was 355,912,000 bushels, and in 1916, 287,533,000 bushels.

There is no carry over of potatoes from the old to the new consumption year. The last of the crop of the former year is disappearing as the early crop of the present year is coming to market. Consequently there is no carry over of potatoes from one consumption year to the next to modify the computed consumption. Since 1900 the lowest consumption of potatoes was 205,754,000 bushels in 1901, and the largest consumption was 418,953,000 bushels in 1912. This is the largest quantity of potatoes ever consumed in this country in one year, and by a large difference exceeds the higher consumptions of other recent years, except the consumption of 1914, which amounted to 407,055,000 bushels.

Potato consumption is almost entirely confined to potatoes produced in this country, as appears when attention is given to the quantities of foreign-produced potatoes. The consumption of foreign potatoes in 1849 was 173,000 bushels, and the quantity had risen to only 234,000 bushels as an average for 1865–1874. In the next 10 years the average yearly consumption of foreign potatoes was 2,158,000 bushels, and the quantity rose to 3,018,000 bushels in the

10 years 1885–1894. This is the highest average consumption of any 10-year period. In the next one the average consumption of foreign potatoes fell to 1,401,000 bushels, and in 1905–1914 the average rose to 2,946,000 bushels.

The foregoing averages, expressing consumption of foreign potatoes, are far from stating the fact understandingly, for the reason that now and then a year of deficient production comes in which there is relatively large importation, although in ordinary years the importations are too small to have any perceptible effect upon national consumption. Except in deficient years, there has been no year in recent times in which the imported potatoes have amounted to as much as 500,000 bushels, and the quantity has usually been much less than that.

In 1910, a year of adequate production, the imports of potatoes were 219,000 bushels, but in the following year when there was a short crop, the imports amounted to 13,729,000 bushels, the largest amount by far ever reached. In the following year the imports fell to 335,000 bushels, but again in 1913 there was some deficiency in production and imports rose to 3,646,000 bushels. In 1914 nominal imports of 370,000 bushels followed, in 1915, 209,000 bushels, and in 1916, 3,069,000 bushels.

FOREIGN POTATOES AS A PERCENTAGE OF TOTAL CONSUMPTION.

Since the home-grown crop usually constitutes nearly the entire consumption of potatoes in this country, it may be sufficient to confine attention to the fraction consumed representing the foreign potatoes, and omit references to the complementary percentages representing the home-grown potatoes. In 1849 0.26 per cent of the entire consumption of potatoes in this country was of foreign potatoes, and the fraction declined to 0.2 per cent in the average for 1866–1874. During the following 10 years the consumption of foreign potatoes increased to 1.3 per cent of the total consumption, and during the next 10 years, 1885–1894, the average was 1.6 per cent. Small though the percentages are, the average for the 10 years 1895–1904 declined to 0.5 per cent, followed by a slight increase to 0.9 per cent, the average for 1905–1914. In 1916 foreign potatoes were 1.1 per cent of the entire national consumption.

PER CAPITA CONSUMPTION.

A conspicuous increase in the per capita consumption of potatoes in this country in recent years is made to appear by computing averages for 10-year periods. The average per capita consumption in 1849 was 2.92 bushels, and the quantity slightly declined to 2.88 bushels during 1866–1874. During the following ten years the consumption increased to 3.25 bushels, after which there was a decline to 2.98 bushels in the subsequent 10-year period, followed by 3.46 bushels in 1895–1904. Increase followed in 1905–1914, during which period the consumption of potatoes per capita was 3.77 bushels. In 1916 the per capita consumption was 2.82 bushels. These are low rates of consumption when comparison is made with various European countries in which the potato is a more prominent article of food.

In years of deficient production of potatoes the imports do not offset the deficiency; they do so only in a small degree, consequently the rates of per capita consumption are determined almost entirely by the per capita production. For this reason a per capita consumption as low as 2.28 bushels is found for 1881, 2.40 bushels for 1887, 2.44 bushels for 1874, and 2.48 bushels for 1890. On the other hand, the highest per capita consumption ever reached in this country, as far as is known, was 4.56 bushels in 1895. Averages next below this are 4.39 bushels in 1912, 4.35 bushels in 1909, and 4.13 bushels in 1914.

The foregoing numbers substantially represent the per capita consumption of domestic potatoes. There is, however, a relatively small consumption of foreign potatoes which amounted to 0.008 of 1 bushel in 1849, and increased to 0.048 of 1 bushel in 1885–1894. During the next 10 years the average consumption of foreign potatoes was 0.019 of 1 bushel, and during the 10 years 1905–1914 the average was 0.032 of 1 bushel. For 1916 the consumption was 0.03 of 1 bushel.

All persons in a family do not eat potatoes and therefore a computed consumption per family may be better understood than the average individual consumption. In 1849 the average family consumption was approximately 16.35 bushels yearly, and the quantity declined during the two 10-year periods 1885–1894 and 1895–1904 to 14.6 and 15.57 bushels per family. During the next 10 years, 1905–1914, the per family consumption attained the highest 10-year average, 16.965 bushels.

The per capita and per family average consumptions above given include potatoes used in this country for all purposes—not only for human food, but for seed, for feeding to live stock, for manufacturing potato starch, and other products, if any, and some degree of waste. In 1899, according to the census report on manufacturers, 3,952,358 bushels of potatoes were used for making potato starch; 3,489,542 bushels in 1904, 3,510,135 bushels in 1909, and 2,831,313 bushels in 1914. The quantities of potatoes so used during these three years were from about 1 to 1½ per cent of the production of potatoes.

The seed requirements of the potato crop in this country have been ascertained by this bureau to be 8.6 bushels per acre as an average for the United States, but with a range of from 7 to 12 bushels in different parts of the country. During the 10-year period 1905–1914 the average production of potatoes per acre was 97.0 bushels, and of this production 8.6 bushels were used for seed, or 8.9 per cent of the crop. Therefore about 10 per cent of the potato crop is used annually for seed and starch making. There is no information concerning the quantity or fraction of the crop fed to live stock. As a matter of general information, however, the fraction is believed to be very small. It appears that if the computed per capita consumption of potatoes is diminished by about one-tenth, the remainder will indicate closely the per capita consumption of this crop for human food, live-stock feed, and waste. After thus making the computation, the per capita consumption of potatoes for human food and animal feed, with unknown waste, was 3.39 bushels during the 10 years 1905–1914, or about 15¼ bushels per family. This average otherwise expressed is equivalent to about 1⅕ pecks per family per week throughout the whole year, and for all the families in the United States. For no 10-year period previous to 1905–1914 has consumption of potatoes in this country per capita and per family been as large as the averages for this period.

PERCENTAGE OF PRODUCTION.

In the 10-year averages the consumption appears to be greater than the production and has been so in fact for the reason that in exceptional years, when production has been very deficient, imports have relatively largely increased for these deficient years. In a consideration of the subject year by year, however, it is certain that since 1894 the more general fact has been that the consumption has been below the production. The difference either way in a consideration by years is usually very small both absolutely and relatively.

During the period 1866–1874 the consumption of potatoes was 99.8 per cent of the production; in 1885–1894 the consumption was 101.4 per cent of the production; in the following 10-year period it was 100.3 per cent; and in 1905–1914 it was 100.4 per cent of the production. In a consideration of this subject by years the percentage is more generally a fraction under 99 per cent than it is above 100 per cent.

Since a portion of the potato crop is always exported, the consumption of home-grown potatoes must necessarily be under 100 per cent of the production. The percentage is almost invariably a fraction under 100, and in only one year since 1865 is it as much as a fraction below 99 per cent of the crop.

PERCENTAGE OF THE SUPPLY.

What has been said under the preceding head concerning the consumption of potatoes as a percentage of production applies without material qualification to the consumption of potatoes as a percentage of the supply. During all years the fraction is usually more than 99½ per cent.

SUMMARY FOR 1905–1914.

The 10-year period 1905–1914 represents statistical conditions in regard to potatoes in this country free of war influences, except in so far as they affect 1914, and the effect of this abnormal year is quite lost in the 10-year average.

During this period 343,394,000 bushels of potatoes were harvested annually from 3,541,000 acres, with an average production of 97.0 bushels per acre, or more per acre than during any previous 10-year period.

The production was 3.76 bushels per capita, or more than in any previous 10-year period, although the production per acre per 1,000,000 population, 1.07 bushels, was less than in any previous 10-year period. Production per acre in relation to population steadily declined from one period to the next until 1905–1914.

During the latest 10-year period the average price of potatoes per bushel at the farm was 59.1 cents, or somewhat higher than at any previous period. This price computes the average total value of the potato crop at the farm at $202,855,000 during this period, so that the average value of this crop per acre during the period was $57.28, or considerably more than at any preceding period. The quantity of the production, still having this period in mind, is 99.1 per cent of the supply, and the value of the production is 99.3 per cent of the value of the supply.

The average imports of potatoes during this period were 2,946,000 bushels, with an import value of $1,506,000, or 51.1 cents per bushel. These imports were 0.86 per cent of the quantity of the production and the value of these imports was 0.74 per cent of the value of the production. Upon making a similar comparison with the supply, it is found that these imports were 0.85 per cent of the quantity of the supply and 0.74 per cent of the value of the supply.

During this period the average annual supply of potatoes in this country has amounted to 346,340,000 bushels, or 3.79 bushels per capita, a ratio that considerably exceeds that of every preceding period. The average value of this supply amounts to $204,361,000.

An average annual export of 1,608,000 bushels of domestic potatoes appears for the 10-year period under consideration, and these potatoes had an average export value of $1,298,000, or 80.7 cents per bushel. The imports of potatoes have increased during the last 30 years, and on the other hand it is plain that the exports of domestic potatoes have considerably increased, although the total is still small. The per capita exports of domestic potatoes in the latest 10-year period are only 0.017 of 1 bushel per capita. The exports of domestic potatoes in this period were 0.47 per cent of the quantity of the production and 0.64 per cent of the value of the production. Corresponding percentages for the supply are nearly the same as those for production. As a percentage of consumption, the exports of domestic potatoes during this period averaged 0.5 per cent.

During this 10-year period the imports of potatoes exceeded the exports of domestic potatoes on the average by 1,339,000 bushels, valued at $208,000, but this preponderance of imports is due to the exceptionally large imports in 1908 and 1911, which were years of very deficient production. The more general fact during the last 20 years is one of surplus of exports of potatoes rather than of imports. The surplus imports of this period are 0.015 of 1 bushel per capita, 0.4 per cent of the quantity of the production, and 0.1 per cent of the value of the production. Related to the consumption of potatoes, the surplus imports of this period were 0.4 per cent.

Potato consumption during the period under review has amounted to 344,733,000 bushels yearly on the average, of which the potatoes of domestic production amounted to 341,786,000 bushels, and foreign potatoes to 2,946,000 bushels. The foreign average is largely determined by the comparatively high imports of 1908 and 1911, whereas the more common fact during the last 20 years is that the foreign potatoes consumed in this country yearly are less than 1,000,000 bushels. Of the entire consumption of potatoes during this period the foreign potatoes were 0.9 per cent and the domestic potatoes were 99.1 per cent.

The per capita consumption of potatoes for all purposes during this period was 3.77 bushels, of which the domestic potatoes were 3.74 bushels and the foreign potatoes 0.032 of 1 bushel. As previously explained, the total per capita consumption of potatoes should be reduced by about one-tenth on account of seed and the manufacture of starch, leaving a per capita consumption of 3.39 bushels yearly during this period for human food, animal feed, and waste.

During this period the consumption of domestic and foreign potatoes was on the average 100.4 per cent of the production, but, as before stated, this result is due to the unusually large imports of 1908 and 1911, the more general fact in recent years being that consumption is slightly less than production. The consumption of domestic potatoes during this period was 99.5 per cent of the production. Computed upon the total supply of potatoes, the total consumption during this period averaged 99.5 per cent.

HISTORICAL TABLES.

The four tables that are appended to the text of this bulletin were prepared and are published especially for their historical value. They constitute a statistical record concerning this principal vegetable crop which in its entirety and in many details has not heretofore been published, and afford a basis upon which to build similar information year by year.

TABLE 1.—*Acreage, production, price, and value of potatoes in the United States, 1849–1917.*

Year, or period.	Harvested acreage.	Production.				Price and value at farm.			Production as a percentage of supply.	
		Total.	Per acre.	Per capita.		Average price per bushel.	Total value.	Average value per acre.	Quantity.	Value.
				Total.	Per acre per 1,000,000 population.					
	Acres.	*Bushels.*	*Bush.*	*Bush.*	*Bush.*	*Cts.*	*Dollars.*	*Dolls.*	*Per ct.*	*Per ct.*
1849......	....	65,797,896	......	2.91	....	......	....	......	99.7	......
1859......	....	111,099,867	......	3.63	....	......	....	......	100.0	......
1866......	1,069,381	107,200,976	100.2	3.00	2.78	47.3	50,722,553	47.43	99.8	99.8
1867......	1,192,195	97,783,000	82.0	2.68	2.28	65.9	64,462,486	54.07	99.8	99.8
1868......	1,131,552	106,090,000	93.8	2.86	2.54	59.3	62,918,660	55.60	99.9	99.9
1869......	1,309,018	143,337,473	109.5	3.79	2.88	42.9	61,491,776	46.98	99.9	99.9
1870......	1,325,119	114,775,000	86.6	2.98	2.22	65.0	74,621,019	56.31	99.6	99.7
1871......	1,220,912	120,461,700	98.7	3.03	2.47	53.9	64,905,189	53.16	99.9	99.9
1872......	1,331,331	113,516,000	85.3	2.78	2.08	53.5	60,692,129	45.59	99.7	99.7
1873......	1,295,139	106,089,000	81.9	2.52	1.95	65.2	69,153,709	53.39	99.5	99.5
1874......	1,310,041	105,981,000	80.9	2.45	1.88	61.5	65,223,314	49.79	99.8	99.7
1875......	1,510,041	166,877,000	110.5	3.76	2.51	34.4	57,357,515	37.98	99.9	99.8
1876......	1,741,983	124,827,000	71.7	2.74	1.56	61.9	77,319,541	44.39	97.5	97.9
1877......	1,792,287	170,092,000	94.9	3.64	2.02	43.7	74,272,500	41.44	99.7	99.7
1878......	1,776,800	124,126,650	69.9	2.59	1.46	58.7	72,923,575	41.04	97.9	98.2
1879......	1,713,433	169,458,539	98.9	3.46	2.02	43.6	73,883,923	43.12	99.6	99.6
1880......	1,842,510	167,659,570	91.0	3.34	1.82	48.3	81,062,214	44.00	98.7	98.9
1881......	2,041,670	109,145,494	53.5	2.12	1.05	91.0	99,291,341	48.63	92.5	95.5
1882......	2,171,636	170,972,508	78.7	3.24	1.48	55.7	95,304,844	43.89	98.6	98.9
1883......	2,289,275	208,164,425	90.9	3.86	1.68	42.2	87,848,991	38.37	99.8	99.8
1884......	2,220,980	190,642,000	85.8	3.44	1.56	39.6	75,524,290	34.00	99.7	99.7
1885......	2,265,823	175,029,000	77.2	3.10	1.35	44.7	78,153,403	34.49	98.9	99.2
1886......	2,287,136	168,051,000	73.5	2.91	1.27	46.7	78,441,940	34.30	99.2	99.3
1887......	2,357,322	134,103,000	56.9	2.27	.96	68.2	91,506,740	38.82	94.2	96.1
1888......	2,533,280	202,365,000	79.9	3.35	1.33	40.2	81,413,589	32.14	99.6	99.6
1889......	2,600,750	201,200,000	77.4	3.26	1.25	35.4	71,294,000	27.41	98.3	98.1
1890......	2,653,000	150,494,000	56.7	2.39	.90	75.3	113,291,000	42.70	96.5	97.6
1891......	2,732,000	256,122,000	93.7	3.99	1.46	35.6	91,229,000	33.39	99.9	99.8
1892......	2,650,000	164,516,000	62.1	2.51	.94	65.5	107,835,000	40.69	97.4	98.1
1893......	2,722,000	195,040,000	71.7	2.92	1.07	58.4	113,886,000	41.84	98.5	98.9
1894......	2,891,000	183,841,000	63.6	2.70	.94	52.9	97,330,000	33.67	99.3	99.4
1895......	3,101,000	317,114,000	102.3	4.56	1.48	26.2	83,151,000	26.81	99.9	99.8
1896......	2,974,000	271,678,000	91.4	3.84	1.29	29.0	78,757,000	26.48	99.9	99.8
1897......	2,813,000	191,025,000	67.9	2.65	.94	54.8	103,442,000	36.77	99.4	99.5
1898......	2,841,000	218,772,000	77.0	2.98	1.05	41.5	90,897,000	31.99	99.8	99.7
1899......	2,938,778	259,027,000	88.6	3.47	1.18	39.6	102,510,000	34.88	99.9	99.9
1900......	2,987,000	247,759,000	82.9	3.26	1.09	42.3	104,764,000	35.07	99.9	99.8
1901......	2,996,000	198,626,000	66.3	2.56	.85	76.3	151,602,000	50.60	96.3	98.0
1902......	3,078,000	293,918,000	95.5	3.71	1.21	46.9	137,730,000	44.75	99.9	99.8
1903......	3,080,000	262,053,000	85.1	3.24	1.05	60.9	159,620,000	51.82	98.8	98.8
1904......	3,172,000	352,268,000	111.1	4.27	1.35	44.8	157,646,000	49.70	99.9	99.9
1905......	3,195,000	278,885,000	87.3	3.32	1.04	61.1	170,340,000	53.31	99.3	99.5
1906......	3,244,000	331,685,000	102.2	3.87	1.19	50.6	167,795,000	51.72	99.9	99.9
1907......	3,375,000	322,954,000	95.7	3.70	1.10	61.3	197,863,000	58.63	99.9	99.9
1908......	3,503,000	302,000,000	86.2	3.40	.97	69.7	210,618,000	60.13	97.3	98.3
1909......	3,668,855	394,553,000	107.5	4.36	1.18	54.2	213,679,000	58.24	99.9	99.9
1910......	3,720,000	349,032,000	93.8	3.79	1.02	55.7	194,566,000	52.30	99.9	99.9
1911......	3,619,000	292,737,000	80.9	3.12	.86	79.9	233,778,000	64.60	95.5	97.0
1912......	3,711,000	420,647,000	113.4	4.41	1.19	50.5	212,550,000	57.28	99.9	99.9
1913......	3,668,000	331,525,000	90.4	3.42	.93	68.7	227,903,000	62.13	98.9	99.2
1914......	3,711,000	409,921,000	110.5	4.16	1.12	48.7	199,460,000	53.75	99.9	99.9
1915......	3,734,000	359,721 000	96.3	3.59	.96	61.7	221,992,000	59.45	99.9	99.8
1916......	3,565,000	286,953,000	80.5	2.82	.79	146.1	419,333,000	117.62	98.9	98.9
1917 (preliminary)....	4,390,000	442,536,000	100.8	4.28	.97	122.9	543,865,000	123.89	......	......
1849......	....	65,797,896	......	2.91	....	......	....	......	99.7	......
1859......	....	111,099,867	......	3.63	....	......	....	......	......	......
1866–1874.	1,242,743	112,803,794	91.0	2.89	2.34	56.6	63,798,982	51.34	99.8	99.8
1875–1884.	1,910,062	160,196,519	84.6	3.22	1.72	49.6	79,478,873	41.61	98.7	98.7
1885–1894.	2,569,231	183,076,000	71.3	2.94	1.15	50.5	92,438,067	35.98	98.4	98.6
1895–1904.	2,998,078	261,224,000	87.1	3.45	1.15	44.8	117,011,900	39.03	99.5	99.4
1905–1914.	3,541,486	343,393,900	97.0	3.76	1.07	59.1	202,855,200	57.28	99.1	99.3

TABLE 2.—*Imports and supply of potatoes of the United States, 1849–1916.*

Year, or period.	Imports, gross, or for consumption.							Supply.		
	Quantity.	Import value.		Percentage of production.		Percentage of supply.		Quantity.		Value.
		Total.	Per bushel.	Quantity.	Value.	Quantity.	Value.	Total.	Per capita.	
	Bushels.	*Dollars.*	*Cents.*	*Bush.*	*Dolls.*	*Bush.*	*Dolls.*	*Bushels.*	*Bush.*	*Dollars.*
1849	172,912	48,635	28.1	0.26	......	0.26	......	65,970,808	2.92	......
1850	299,132	94,441	31.6	......	......	......	......	......	......	......
1851	322,223	119,388	37.1	......	......	......	......	......	......	......
1852	353,082	92,870	26.3	......	......	......	......	......	......	......
1853	306,187	118,747	38.8	......	......	......	......	......	......	......
1854	......	318,932	......	......	......	......	......	......	......	......
1855	535,320	270,798	50.6	......	......	......	......	......	......	......
1856	693,611	442,476	63.8	......	......	......	......	......	......	......
1857	......	644,915	......	......	......	......	......	......	......	......
1858	......	512,744	......	......	......	......	......	......	......	......
1859	......	478,255	......	......	......	......	......	111,099,867	3.63	......
1860	753,511	289,227	38.4	......	......	......	......	......	......	......
1861	837,223	342,709	40.9	......	......	......	......	......	......	......
1862	327,315	174,207	53.2	......	......	......	......	......	......	......
1863	4,497	4,487	99.8	......	......	......	......	......	......	......
1864	10,955	12,155	111.0	......	......	......	......	......	......	......
1865	78,194	46,804	59.9	......	......	......	......	......	......	......
1866	198,265	87,795	44.3	.19	0.17	.18	0.17	107,399,241	3.01	50,810,348
1867	209,555	128,465	61.3	.22	.20	.21	.20	97,992,555	2.69	64,590,951
1868	138,470	76,327	55.1	.13	.12	.13	.12	106,228,470	2.86	62,994,987
1869	75,336	50,507	67.0	.05	.08	.05	.08	143,412,809	3.79	61,542,283
1870	458,758	234,303	51.1	.40	.31	.40	.31	115,233,758	2.99	74,855,322
1871	96,259	95,308	99.0	.08	.15	.08	.15	120,557,959	3.04	65,000,497
1872	346,840	209,294	60.3	.30	.34	.30	.34	113,862,840	2.79	60,901,423
1873	549,073	331,370	60.4	.52	.48	.51	.48	106,638,073	2.54	69,485,079
1874	188,757	166,981	88.5	.18	.26	.18	.26	106,169,757	2.46	65,390,295
1875	92,148	130,361	141.5	.05	.23	.06	.23	166,969,148	3.76	57,487,876
1876	3,205,555	1,652,963	51.6	2.57	2.14	2.50	2.09	128,032,555	2.81	78,972,504
1877	528,584	245,515	46.4	.31	.33	.31	.33	170,620,584	3.66	74,518,015
1878	2,624,149	1,345,744	51.3	2.11	1.85	2.07	1.81	126,750,799	2.65	74,269,319
1879	721,868	276,454	38.3	.43	.37	.42	.37	170,180,407	3.47	74,160,377
1880	2,170,372	874,223	40.3	1.29	1.08	1.28	1.07	169,829,942	3.39	81,936,437
1881	8,789,860	4,660,120	53.0	8.05	4.69	7.45	4.48	117,935,354	2.29	103,951,461
1882	2,362,362	1,092,211	46.2	1.38	1.15	1.36	1.13	173,334,870	3.29	96,397,055
1883	425,408	193,623	45.5	.21	.22	.20	.22	208,589,833	3.86	88,042,614
1884	658,633	255,590	38.8	.35	.34	.34	.34	191,300,633	3.46	75,779,880
1885	1,937,416	649,009	33.5	1.10	.83	1.09	.82	176,966,416	3.13	78,802,412
1886	1,432,490	543,091	37.9	.85	.69	.85	.69	169,483,490	2.93	78,985,031
1887	8,259,538	3,693,021	44.7	6.16	4.04	5.80	3.88	142,362,538	2.41	95,199,761
1888	883,380	321,106	36.3	.43	.39	.43	.39	203,248,380	3.37	81,734,695
1889	3,415,578	1,365,898	40.0	1.70	1.92	1.67	1.88	204,615,578	3.32	72,659,898
1890	5,401,912	2,797,927	51.8	3.59	2.47	3.47	2.41	155,895,912	2.48	116,088,927
1891	186,871	186,006	99.5	.07	.20	.07	.20	256,308,871	3.99	91,415,006
1892	4,317,021	2,066,589	47.9	2.62	1.92	2.56	1.88	168,833,021	2.58	109,901,589
1893	3,002,578	1,277,194	42.5	1.54	1.12	1.52	1.11	198,042,578	2.96	115,163,194
1894	1,341,533	603,554	45.0	.73	.62	.72	.62	185,182,533	2.72	97,933,554
1895	175,240	127,595	72.8	.06	.15	.06	.15	317,289,240	4.57	83,278,595
1896	246,178	145,584	59.1	.09	.18	.09	.18	271,924,178	3.84	78,902,584
1897	1,171,378	473,154	40.4	.61	.46	.61	.46	192,196,378	2.67	103,915,154
1898	530,420	294,391	55.5	.24	.32	.24	.32	219,302,420	2.99	91,191,391
1899	155,861	147,349	94.5	.06	.14	.06	.14	259,182,861	3.47	102,657,349
1900	371,911	224,759	60.4	.15	.21	.15	.21	248,130,911	3.27	104,988,759
1901	7,656,162	3,160,801	41.3	3.85	2.08	3.71	2.04	206,282,162	2.66	154,762,801
1902	358,505	238,445	66.5	.12	.17	.12	.17	294,276,505	3.71	137,968,445
1903	3,166,581	1,870,004	59.1	1.21	1.17	1.19	1.16	265,219,581	3.28	161,490,004
1904	181,199	168,094	92.8	.05	.11	.05	.11	352,449,199	4.27	157,814,094
1905	1,948,160	853,063	43.8	.70	.50	.69	.50	280,833,160	3.34	171,193,063
1906	176,917	192,635	108.9	.05	.11	.05	.11	331,861,917	3.87	167,987,635
1907	403,952	283,032	70.1	.12	.14	.12	.14	323,357,952	3.70	198,146,032
1908	8,383,966	3,677,034	43.9	2.77	1.75	2.70	1.72	310,383,966	3.49	214,295,034
1909	353,208	306,815	86.9	.09	.14	.09	.14	394,906,208	4.36	213,985,815
1910	218,984	235,847	107.7	.06	.12	.06	.12	349,250,984	3.79	194,801,847
1911	13,729,012	7,167,480	52.2	4.69	3.07	4.48	2.97	306,466,012	3.27	240,945,480
1912	334,760	302,584	90.4	.08	.14	.08	.14	420,981,760	4.41	212,852,584
1913	3,645,706	1,765,940	48.4	1.10	.77	1.09	.77	335,170,706	3.45	229,668,940
1914	269,725	274,242	101.7	.07	.14	.07	.14	410,190,725	4.16	199,734,242
1915	209,052	331,631	158.6	.06	.15	.06	.15	359,930,052	3.59	222,323,631
1916 (preliminary)	3,069,014	4,702,408	153.2	1.07	1.12	1.06	1.11	290,022,014	2.85	424,035,408
1849	172,912	48,635	28.1	.26	......	.26	......	65,970,808	2.92	......
1850–1854	4*320,156	148,876	4*33.2	......	......	......	......	......	......	......
1855–1864	7*451,776	317,197	7*48.6	......	......	......	......	......	......	......
1865–1874	233,951	142,715	61.0	9*.22	9*.24	9*.22	9*.24	9*113,055,051	9*2.89	9*63,952,354
1875–1884	2,157,894	1,072,680	49.7	1.35	1.35	1.33	1.33	162,354,413	3.27	80,551,553
1885–1894	3,017,832	1,350,340	44.7	1.65	1.46	1.62	1.44	186,093,932	2.99	93,788,407
1895–1904	1,401,344	685,018	48.9	.54	.59	.53	.58	262,625,344	3.47	117,697,018
1905–1914	2,946,439	1,505,867	51.1	.86	.74	.85	.74	346,340,339	3.79	204,361,067

TABLE 3.—*Domestic exports and foreign trade surplus of potatoes of the United States, 1849–1916.*

Year or period.	Domestic exports.									Surplus exports.					
	Quantity.		Export value.		Percentage of production.		Percentage of supply.		Per centage of consumption, quantity.	Quantity.		Value.	Percentage of production.		Per centage of consumption, quantity.
	Total.	Per capita of population.	Total.	Per bushel.	Quantity.	Value.	Quantity.	Value.		Total.	Per capita.		Quantity.	Value.	
	Bushels.	*Bushels.*	*Dollars.*	*Cents.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Bushels.*	*Bushels.*	*Dollars.*	*Per cent.*	*Per cent.*	*Per cent.*
1849	155,595	0.007	99,333	63.8	0.24	....	0.24	....	0.24	[1] 17,317	[1] 0.001	50,698	0.03	....	[1] 0.03
1850	106,342	.005	79,314	74.6	....	....	....	....	....	[1] 192,790	[1] .008	[1] 15,127	....	....	....
1851	148,916	.006	115,121	77.3	....	....	....	....	....	[1] 173,307	[1] .007	[1] 4,267	....	....	....
1852	225,905	.009	152,569	67.5	....	....	....	....	....	[1] 127,177	[1] .005	59,699	....	....	....
1853	140,575	.005	121,680	86.6	....	....	....	....	....	[1] 165,612	[1] .006	2,933	....	....	....
1854	[2] 225,013	[2] .008	203,416	90.4	....	....	....	....	....	....	.008	[1] 115,516	....	....	....
1855	[2] 226,908	[2] .008	153,061	67.5	....	....	....	....	....	[1] 308,412	[1] .011	[1] 117,737	....	....	....
1856	[2] 238,722	[2] .008	205,616	86.1	....	....	....	....	....	[1] 454,889	[1] .016	[1] 236,860	....	....	....
1857	242,231	.008	205,791	85.0	....	....	....	....	....	....	.008	[1] 439,124	....	....	....
1858	376,056	.013	284,111	75.6	....	....	....	....	....	....	.013	[1] 228,633	....	....	....
1859	380,372	.013	284,673	74.8	.34	....	0.34	....	....	....	.012	[1] 193,582	.34	....	....
1860	413,091	.013	285,508	69.1	....	....	....	....	....	[1] 340,420	[1] .011	[1] 3,719	....	....	....
1861	417,138	.013	295,865	70.9	....	....	....	....	....	[1] 420,085	[1] .013	[1] 46,844	....	....	....
1862	517,530	.016	301,664	58.3	....	....	....	....	....	190,215	.006	127,457	....	....	....
1863	463,212	.014	303,400	65.5	....	....	....	....	....	458,715	.014	298,913	....	....	....
1864	538,001	.016	374,360	69.6	....	....	....	....	....	527,046	.015	362,205	....	....	....
1865	470,753	.013	381,372	81.0	....	....	....	....	....	....	.011	334,568	....	....	....
1866	512,380	.015	358,777	70.0	.48	0.71	.48	0.71	.48	314,115	.009	270,982	.29	0.53	.29
1867	378,605	.011	345,529	91.3	.39	.54	.39	.53	.39	169,050	.005	217,064	.17	.34	.17
1868	508,249	.014	328,316	64.6	.48	.52	.48	.52	.48	369,779	.010	251,989	.35	.40	.35
1869	596,968	.015	334,540	56.0	.42	.54	.42	.54	.42	521,632	.014	284,033	.36	.46	.37
1870	553,070	.015	384,042	69.4	.48	.51	.48	.51	.48	94,312	.002	149,739	.08	.20	.08
1871	621,537	.016	431,707	69.5	.52	.67	.52	.66	.52	525,278	.013	336,399	.44	.52	.44
1872	515,306	.013	434,809	84.4	.45	.72	.45	.71	.45	168,466	.004	225,515	.15	.37	.15
1873	497,413	.012	420,832	84.6	.47	.61	.47	.61	.47	[1] 51,660	[1] .001	89,462	[1] .05	.13	[1] .05
1874	609,642	.014	463,338	76.0	.58	.71	.57	.71	.58	420,885	.010	296,357	.40	.45	.40
1875	704,379	.016	378,791	53.8	.42	.66	.42	.66	42	612,231	.014	248,430	.37	.43	.37
1876	529,650	.011	494,149	93.3	.42	.64	.41	.63	.42	[1] 2,675,905	[1] .059	[1] 1,158,814	[1] 2.14	[1] 1.50	[1] 2.10
1877	744,409	.016	528,383	71.0	.44	.71	.44	.71	.44	215,825	.005	282,868	.13	.38	.13
1878	625,342	.013	544,021	87.0	.50	.75	.49	.73	.50	[1] 1,998,807	[1] .042	[1] 801,723	[1] 1.61	[1] 1.10	[1] 1.58

[1] Surplus imports.

[2] This quantity has been computed by converting shipment in barrels into shipments in bushels at rate of 2¾ bushels to 1 barrel.

TABLE 3.—*Domestic exports and foreign trade surplus of potatoes of the United States, 1849–1916*—Continued.

Year or period.	Domestic exports.									Surplus exports.					
	Quantity.		Export value.		Percentage of production.		Percentage of supply.		Per centage of consumption, quantity.	Quantity.		Value.	Percentage of production.		Per centage of consumption, quantity.
	Total.	Per capita of population.	Total.	Per bushel.	Quantity.	Value.	Quantity.	Value.		Total.	Per capita.		Quantity.	Value.	
	Bushels.	*Bushels.*	*Dollars.*	*Cents.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Bushels.*	*Bushels.*	*Dollars.*	*Per cent.*	*Per cent.*	*Per cent.*
1879	696,080	.015	522,039	75.0	.41	.71	.41	.70	.41	[1]25,788	[1].001	245,585	[1].02	.31	[1].02
1880	638,840	.013	460,517	72.1	.38	.57	.38	.56	.38	[1]1,531,532	[1].031	[1]413,706	[1].91	[1].51	[1].91
1881	408,286	.008	441,816	108.2	.37	.44	.35	.43	.35	[1]8,381,574	[1].163	[1]4,218,304	[1]7.68	[1]4.25	[1]7.13
1882	439,443	.008	428,478	97.5	.26	.45	.25	.44	.25	[1]1,922,919	[1].036	[1]663,733	[1]1.12	[1].70	[1]1.11
1883	554,613	.010	374,588	67.5	.27	.43	.27	.43	.27	129,205	.002	180,965	.06	.21	.06
1884	380,868	.007	265,355	69.7	.20	.35	.20	.35	.20	[1]277,765	[1].005	9,765	[1].28	.01	[1].15
1885	494,948	.008	346,864	70.1	.28	.44	.28	.44	.28	[1]1,442,468	[1].026	[1]302,145	[1].82	[1].39	[1].82
1886	434,864	.008	318,259	73.2	.26	.41	.26	.40	.26	[1]997,626	[1].017	[1]224,832	[1].59	[1].29	[1].59
1887	403,880	.007	308,193	76.3	.30	.34	.28	.32	.28	[1]7,855,658	[1].133	[1]3,384,828	[1]5.86	[1]3.70	[1]5.53
1888	471,955	.008	316,224	67.0	.23	.39	.23	.39	.23	[1]411,425	[1].007	[1]4,882	[1].20	[1].01	[1].20
1889	406,618	.007	269,693	66.3	.20	.38	.20	.37	.20	[1]3,008,960	[1].049	[1]1,096,205	[1]1.50	[1]1.54	[1]1.47
1890	341,189	.006	316,482	92.8	.23	.28	.22	.27	.22	[1]5,060,723	[1].080	[1]2,481,445	[1]3.36	[1]2.21	[1]3.25
1891	557,022	.009	361,378	64.9	.22	.40	.22	.40	.22	370,151	.006	175,372	.14	.19	.14
1892	845,720	.013	700,032	82.8	.51	.65	.50	.64	.50	[1]3,471,301	[1].053	[1]1,366,557	[1]2.11	[1]1.32	[1]2.07
1893	803,111	.012	651,877	81.2	.41	.57	.41	.57	.41	[1]2,199,467	[1].033	[1]625,317	[1]1.13	[1].58	[1]1.12
1894	572,957	.009	418,221	73.0	.31	.43	.31	.43	.31	[1]768,576	[1].011	[1]185,333	[1].42	[1].20	[1].42
1895	680,049	.010	371,485	54.6	.21	.45	.21	.45	.21	504,809	.007	243,890	.16	.33	.16
1896	926,646	.013	515,067	55.6	.34	.65	.34	.65	.34	680,468	.010	369,483	.25	.51	.25
1897	605,187	.008	460,666	76.1	.32	.45	.31	.44	.32	[1]566,191	[1].008	[1]12,488	[1].30	.01	[1].30
1898	579,833	.008	450,739	77.7	.27	.50	.26	.49	.27	49,413	.001	156,348	.02	.20	.02
1899	809,472	.010	626,791	77.4	.31	.61	.31	.61	.31	653,611	.009	479,442	.25	.47	.25
1900	741,483	.010	518,621	69.9	.30	.50	.30	.49	.30	369,572	.005	293,862	.18	.32	.15
1901	528,484	.007	564,550	106.8	.27	.37	.26	.36	.26	[1]7,127,678	[1].092	[1]2,596,251	[1]3.80	[1]1.80	[1]3.46
1902	843,075	.011	552,533	65.5	.29	.40	.29	.40	.29	484,570	.006	314,088	.17	.23	.17
1903	484,042	.006	436,135	90.1	.19	.27	.18	.27	.18	[1]2,682,539	[1].033	[1]1,433,869	[1]1.08	[1].95	[1]1.01
1904	1,163,270	.014	750,210	64.5	.33	.48	.33	.48	.33	982,071	.012	582,116	.30	.39	.28
1905	1,000,326	.012	743,993	74.4	.36	.44	.36	.43	.36	[1]947,834	[1].011	[1]109,070	[1].36	.07	[1].34
1906	1,530,461	.018	1,278,034	83.5	.46	.76	.46	.76	.46	1,353,544	.016	1,085,399	.44	.69	.41
1907	1,203,894	.013	1,077,612	89.5	.37	.54	.37	.54	.37	799,942	.009	794,580	.27	.43	.25
1908	763,651	.009	715,701	93.7	.25	.34	.25	.33	.25	[1]7,620,315	[1].086	[1]2,961,333	[1]2.73	1.50	[1]2.46
1909	999,476	.011	759,277	76.0	.25	.36	.25	.35	.25	646,268	.007	452,462	.16	.21	.16

1910	2,383,887	.026	1,535,630	64.4	.68	.79	.68	.79	.69.	2,164,903	.023	1,299,783	.62	.67	.62
1911	1,237,276	.013	1,414,297	114.3	.42	.60	.40	.59	.41	[1] 12,491,736	[1] .133	[1] 5,753,183	[1] 4.27	[1] 2.46	[1] 4.09
1912	2,028,261	.021	1,646,176	81.2	.48	.77	.48	.77	.48	1,693,501	.018	1,343,592	.40	.63	.40
1913	1,794,073	.019	1,463,514	81.6	.54	.64	.54	.64	.54	[1] 1,851,633	.019	[1] 302,426	[1] .56	[1] .13	[1] .56
1914	3,135,474	.032	2,345,731	74.8	.76	1.18	.76	1.17	.77	2,865,749	.029	2,071,489	.70	1.04	.70
1915	4,017,760	.040	3,485,740	86.8	1.12	1.57	1.12	1.56	1.13	3,808,708	.038	3,154,109	1.06	1.42	1.07
1916 (preliminary)	2,489,001	.024	3,514,379	141.2	.87	.84	.86	.83	.87	[1] 580,043	[1] .006	[1] 1,188,029	[1] .20	[1] .28	[1] .20
1849	155,595	.007	99,333	63.8	.24	....	.24	....	0.2	[1] 17,317	[1] .001	50,698	.03	....	[1] 0.03
1850-1854	169,350	.006	134,420	79.4	....	....	....	....	....	4*[1] 164,722	[1] .007	[1] 14,456	....	....	....
1855-1864	381,326	.012	269,405	70.6	1*.34	....	....	....	....	9*[1] 49,690	7*[1] .002	[1] 47,792	....	....	....
1865-1874	526,392	.014	388,326	73.8	9*.47	9*.61	9*.47	9*.61	9*0.5	292,441	.008	245,611	9*.24	9*.36	9*0.3
1875-1884	572,191	.011	443,814	77.6	.36	.56	.35	.55	0.4	[1] 1,585,703	[1] .032	[1] 628,866	[1] .99	[1] .79	[1] 0.9
1885-1894	533,226	.009	400,722	75.2	.29	.43	.29	.43	0.3	[1] 2,484,606	[1] .040	[1] 949,618	[1] 1.36	[1] 1.03	[1] 1.3
1895-1904	736,154	.010	524,680	71.3	.28	.45	.28	.45	0.3	[1] 665,190	[1] .009	[1] 160,338	[1] .25	[1] .14	[1] 0.3
1905-1914	1,607,678	.017	1,297,996	80.7	.47	.64	.46	.64	0.5	[1] 1,338,761	[1] .015	[1] 207,871	[1] .39	[1] .10	[1] 0.4

[1] Surplus imports.

NOTE.—Every average for less than 10 years is preceded by a (*) and that is preceded by a figure indicating the number of years represented.

TABLE 4.—*Consumption of potatoes in the United States, 1849–1916.*

Year, or period.	Consumption.										
	Total.	Domestic.	Foreign.	Percentage of total.		Per capita.			Percentage of production.		Percentage of supply.
				Domestic.	Foreign.	Total.	Domestic.	Foreign.	Total consumption.	Domestic consumption.	
	Bushels.	*Bushels.*	*Bushels.*	*Per ct.*	*Per ct.*	*Bush.*	*Bush.*	*Bush.*	*Per ct.*	*Per ct.*	*Per ct.*
1849	65,815,213	65,642,301	172,912	99.7	0.26	2.92	2.91	0.008	100.0	99.8	99.8
1850	......	......	299,132	......	......	......	......	.013	......	......	......
1851	......	......	322,223	......	......	......	......	.013	......	......	......
1852	......	......	353,082	......	......	......	......	.014	......	......	......
1853	......	......	306,187	......	......	......	......	.012	......	......	......
1854	......	......	......	......	......	......	......	......	......	......	......
1855	......	......	535,320	......	......	......	......	.020	......	......	......
1856	......	......	693,611	......	......	......	......	.025	......	......	......
1857	......	......	......	......	......	......	......	......	......	......	......
1858	......	......	......	......	......	......	......	......	......	......	......
1859	......	110,719,495	......	......	......	......	3.62	......	......	99.7	......
1860	......	......	753,511	......	......	......	......	.024	......	......	......
1861	......	......	837,223	......	......	......	......	.026	......	......	......
1862	......	......	327,315	......	......	......	......	.010	......	......	......
1863	......	......	4,497	......	......	......	......	......	......	......	......
1864	......	......	10,955	......	......	......	......	......	......	......	......
1865	......	......	78,194	......	......	......	......	.002	......	......	......
1866	106,886,861	106,688,596	198,265	99.8	.19	2.99	2.99	.006	99.7	99.5	99.5
1867	97,613,950	97,404,395	209,555	99.8	.21	2.68	2.67	.006	99.8	99.6	99.6
1868	105,720,221	105,581,751	138,470	99.9	.13	2.85	2.84	.004	99.7	99.5	99.5
1869	142,815,841	142,740,505	75,336	99.9	.05	3.77	3.77	.002	99.6	99.6	99.6
1870	114,680,688	114,221,930	458,758	99.6	.40	2.97	2.96	.012	99.9	99.5	99.5
1871	119,936,422	119,840,163	96,259	99.9	.08	3.02	3.02	.003	99.6	99.5	99.5
1872	113,347,534	113,000,694	346,840	99.7	.31	2.77	2.76	.009	99.9	99.6	99.5
1873	106,140,660	105,591,587	549,073	99.5	.52	2.52	2.51	.013	100.0	99.5	99.5
1874	105,560,115	105,371,358	188,757	99.8	.18	2.44	2.44	.005	99.6	99.4	99.4
1875	166,264,769	166,172,621	92,148	99.9	.06	3.75	3.75	.002	99.6	99.6	99.6
1876	127,502,905	124,297,350	3,205,555	97.5	2.51	2.80	2.73	.070	102.1	99.6	99.6
1877	169,876,175	169,347,591	528,584	99.7	.31	3.64	3.63	.011	99.9	99.6	99.6
1878	126,125,457	123,501,308	2,624,149	97.9	2.08	2.64	2.58	.055	101.6	99.5	99.5
1879	169,484,327	168,762,459	721,868	99.6	.43	3.46	3.44	.015	100.0	99.6	99.6
1880	169,191,102	167,020,730	2,170,372	98.7	1.28	3.37	3.33	.043	100.9	99.6	99.6
1881	117,527,068	108,737,208	8,789,860	92.5	7.48	2.28	2.11	.171	107.7	99.6	99.7
1882	172,895,427	170,533,065	2,362,362	98.6	1.37	3.28	3.24	.045	101.1	99.8	99.7
1883	208,035,220	207,609,812	425,408	99.8	.20	3.85	3.85	.008	99.9	99.7	99.7
1884	190,919,765	190,261,132	658,633	99.7	.34	3.45	3.44	.012	100.2	99.8	99.8
1885	176,471,468	174,534,052	1,937,416	98.9	1.10	3.12	3.09	.034	100.8	99.7	99.7
1886	169,048,626	167,616,136	1,432,490	99.2	.85	2.92	2.90	.025	100.6	99.7	99.7
1887	141,958,658	133,699,120	8,259,538	94.2	5.82	2.40	2.26	.140	105.9	99.7	99.7
1888	202,776,425	201,893,045	883,380	99.6	.44	3.36	3.34	.015	100.2	99.8	99.8
1889	204,208,960	200,793,382	3,415,578	98.3	1.67	3.31	3.26	.055	101.5	99.8	99.8
1890	155,554,723	150,152,811	5,401,912	96.5	3.47	2.48	2.39	.086	103.4	99.8	99.8
1891	255,751,849	255,564,978	186,871	99.9	.07	3.98	3.98	.003	99.9	99.8	99.8
1892	167,987,301	163,670,280	4,317,021	97.4	2.57	2.57	2.50	.066	102.1	99.5	99.5
1893	197,239,467	194,236,889	3,002,578	98.5	1.52	2.96	2.91	.045	101.1	99.6	99.6
1894	184,609,576	183,268,043	1,341,533	99.3	.73	2.71	2.69	.020	100.4	99.7	99.7
1895	316,609,191	316,433,951	175,240	99.9	.06	4.56	4.55	.003	99.8	99.8	99.8
1896	270,997,532	270,751,354	246,178	99.9	.09	3.83	3.83	.003	99.7	98.7	99.7
1897	191,591,191	190,419,813	1,171,378	99.4	.61	2.66	2.64	.016	100.3	99.7	99.7
1898	218,722,587	218,192,167	530,420	99.8	.24	2.98	2.97	.007	100.0	99.7	99.7
1899	258,373,389	258,217,528	155,861	99.9	.06	3.46	3.46	.002	99.7	99.7	99.7
1900	247,389,428	247,017,517	371,911	99.8	.15	3.26	3.25	.005	99.9	99.7	99.7
1901	205,753,678	198,097,516	7,656,162	96.3	3.72	2.65	2.55	.099	103.6	99.7	99.7
1902	293,433,430	293,074,925	358,505	99.9	.12	3.70	3.70	.005	99.8	99.7	99.7
1903	264,735,539	261,568,958	3,166,581	98.8	1.20	3.27	3.24	.039	101.0	99.8	99.8
1904	351,285,929	351,104,730	181,199	99.95	.05	4.26	4.26	.002	99.7	99.7	99.7
1905	279,832,834	277,884,674	1,948,160	99.3	.70	3.33	3.30	.023	100.3	99.6	99.6
1906	330,331,456	330,154,539	176,917	99.9	.05	3.85	3.85	.002	99.6	99.5	99.5
1907	322,154,058	321,750,106	403,952	99.9	.13	3.69	3.68	.004	99.8	99.6	99.6
1908	309,620,315	301,236,349	8,383,966	97.3	2.71	3.48	3.39	.094	102.5	99.8	99.8
1909	393,906,732	393,553,524	353,208	99.9	.09	4.35	4.35	.004	99.8	99.7	99.7
1910	346,867,097	346,648,113	218,984	99.9	.06	3.76	3.76	.002	99.4	99.3	99.3
1911	305,228,736	291,499,724	13,729,012	95.5	4.50	3.25	3.11	.146	104.3	99.6	99.6
1912	418,953,499	418,618,739	334,760	99.9	.08	4.39	4.39	.003	99.6	99.5	99.5
1913	333,376,633	329,730,927	3,645,706	98.9	1.09	3.44	3.40	.038	100.6	99.5	99.5
1914	407,055,251	406,785,526	269,725	99.9	.07	4.13	4.12	.003	99.3	99.2	99.2
1915	355,912,292	355,703,240	209,052	99.9	.06	3.55	3.55	.002	98.9	98.9	98.9
1916(prelm)	287,533,013	284,463,999	3,069,014	98.9	1.07	2.82	2.79	.030	100.2	99.1	99.1
1849	65,815,213	65,642,301	172,912	99.7	.3	2.92	2.91	.008	100.0	99.8	99.8
1850–1854	......	......	4*320,156	......	......	......	......	4*.013	......	......	......
1855–1864	......	110,719,495	7*451,776	......	......	......	1*3.62	7*.014	......	1*99.7	......
1865–1874	9*112,522,477	112,271,220	233,951	9*99.8	9*.2	9*2.88	9*2.88	9*.006	9*99.8	9*99.5	9*99.5
1875–1884	161,782,222	159,624,328	2,157,894	98.7	1.3	3.25	3.21	.043	101.0	99.6	99.6
1885–1894	185,560,705	182,542,874	3,017,832	98.4	1.6	2.98	2.93	.048	101.4	99.7	99.7
1895–1904	261,889,189	260,487,846	1,401,344	99.5	0.5	3.46	3.44	.019	100.3	99.7	99.7
1905–1914	344,732,661	341,786,222	2,946,439	99.1	0.9	3.77	3.74	.032	100.4	99.5	99.5

UNITED STATES DEPARTMENT OF AGRICULTURE

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LEON M, ESTABROOK, Chief

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GEOGRAPHICAL PHASES OF FARM PRICES: CORN.

By L. B. Zapoleon,

Division of Crop Records.

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SCOPE OF SUBJECT OUTLINED.

Yields to the acre are a measure of physical limitations, and producers' prices reflect commercial factors.

Analysis of extreme sectional differences in prices paid to farmers discloses zones of uniformly high or low prices, between which prices graduate. This price advantage or disadvantage varies with each product.

The geography of farm prices constitutes a controlling element in local types of agriculture.

In the foreground of the present-day problems are those having to do with the prices of food products. The importance of geographic factors in producers' and consumers' prices is not apparent in the middle ground represented by average prices and price levels, for great differences usually prevail in the prices of a specific product in various sections of the country. The trend of this local variation differs for each commodity. The lowest wheat prices, for instance, occur in areas wherein relatively high prices prevail for corn. In the South lower production, higher prices, and smaller consumption of wheat and other cereals go hand in hand.

Such price differences are not accidental; they are traceable to fundamental conditions which in many instances are contrary to the general tendencies. Particularly is this true in the producers' price, or "farm price," which is the basic as well as the first and lowest price of food products.

The present investigation is confined chiefly to the influence of producing areas, trade routes, and consuming centers upon prices paid to farmers for corn and to a survey of the regional differences in such prices.

Existing types of agriculture are determined by a combination of physical and commercial factors. Physical limitations upon most agricultural products may be said to be measured by the average yield in bushels to the acre. High or low yields per acre decrease or increase costs of production. It is also apparent that commercial limitations on production are to a large degree reflected in the price obtained by the farmer.

When the varying farm prices of a product are properly charted on a map they are seen to increase or decrease in determinate directions. The regions of lowest and of highest prices are thus shown clearly, also regions or zones of intermediate prices. The directions of the price movement vary with each product. Small areas appear where farm prices are higher or lower than in the surrounding territory or zone.

The "geography of farm prices" is thus a controlling element in crop selection. Climate and soil are, of course, the dominating physical factors which determine local types of agriculture. But the local farm price is an index of commercial conditions that are hardly less important. Given a sufficiently high price, obviously products could be grown profitably under unfavorable physical conditions.

DATA EMPLOYED AND METHOD OF TREATMENT.

"Isotimes," the term used for lines bounding areas of like price.

Counties as basis of measurement, and a five-year average employed to distinguish normal from spasmodic price differences.

To the lines delimiting areas of like price the term "isotimes" (price lines) has been given,[1] similar to "isotherms" and "isobars" as applied to lines running through points of like temperature or barometric pressure. Just as the course of climatic changes is outlined in the latter two so are local or general commercial disturbances reflected in the isotimes.

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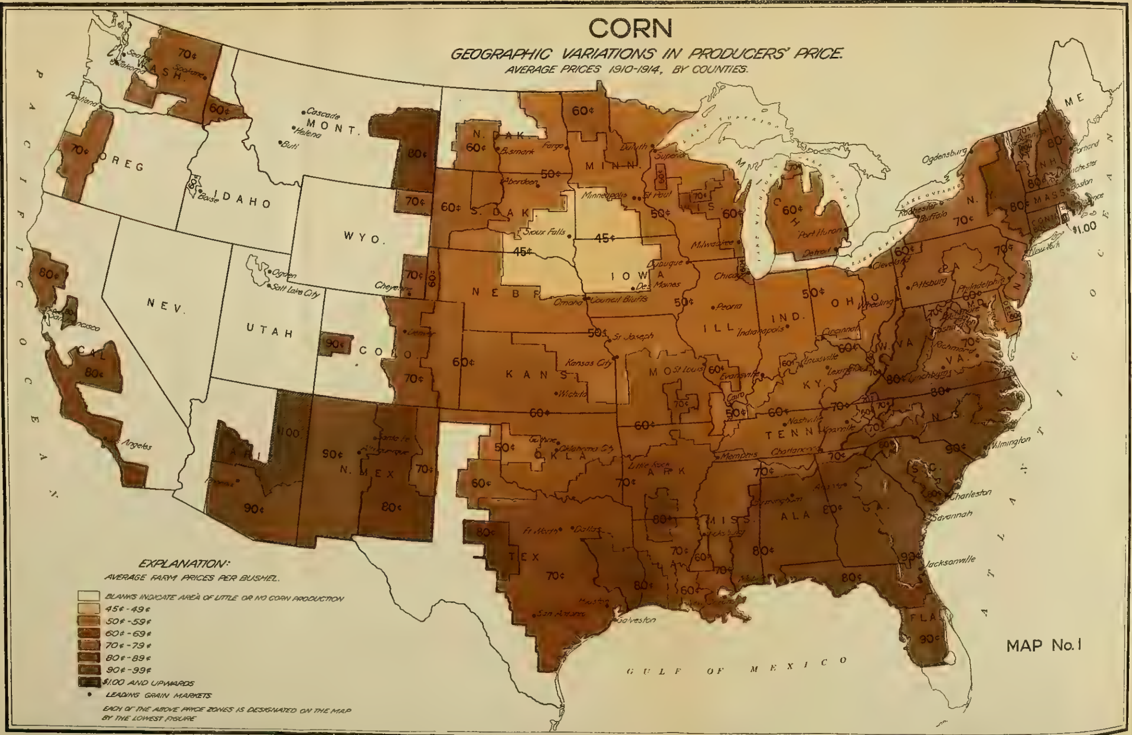
[1] Th. H. Engelbrecht.



CORN

GEOGRAPHIC VARIATIONS IN PRODUCERS' PRICE.

AVERAGE PRICES 1910-1914, BY COUNTIES.

EXPLANATION:

AVERAGE FARM PRICES PER BUSHEL.

☐ BLANKS INDICATE AREA OF LITTLE OR NO CORN PRODUCTION
▨ 45¢ - 49¢
▨ 50¢ - 59¢
▨ 60¢ - 69¢
▨ 70¢ - 79¢
▨ 80¢ - 89¢
▨ 90¢ - 99¢
▨ $1.00 AND UPWARDS
● LEADING GRAIN MARKETS

EACH OF THE ABOVE PRICE ZONES IS DESIGNATED ON THE MAP BY THE LOWEST FIGURE

MAP No. 1

THE NORRIS PETERS CO., WASHINGTON, D.

The county has been used as the basis of measurement in this bulletin. It represents the smallest unit of area for which farm prices are to be had. The base figures were compiled from the annual reports of about 30,000 township reporters of the Bureau of Crop Estimates for December 1, 1910–1914, inclusive. Five-year averages were used instead of quotations for a single year, in order to represent more nearly normal rather than occasional conditions.

A tabular presentation of the prices of corn, by States and counties, is given in the Appendix (p. 45). Geographic variation of prices is depicted by means of maps and graphs.

SURVEY OF BROAD REGIONAL DIFFERENCES IN CORN PRICES.

Low prices prevail throughout the great corn States, from Ohio to Nebraska; the minimum price paid to producers of corn appears at the northwestern end of this section.

This area of lowest price forms a price depression; prices attain constantly higher levels toward all points of the compass, at varying degrees of increase.

Maximum prices are paid usually to growers in producing areas farthest from the corn belt—in the Southwest and Southeast.

Although the farm prices of corn will be seen to increase or decrease in definable directions, this movement is somewhat irregular. On Map 1 a 10-cent price unit has been used to overcome minor local deviations and show more clearly the general trend of the price levels. Blank spaces on this map indicate areas of little or no corn production, according to the 1910 census.

It will be observed that the difference in farm prices between the highest and lowest region exceeds 60 cents per bushel, or a variation of nearly 150 per cent. Under usual conditions the isotimes, or degrees of sectional price difference, as they are delimited on the map, prevail without regard to oscillations in the general price level of corn.

The lowest prices paid to corn growers occur within the areas of densest production—from western Ohio, across the corn belt, through the greater part of Nebraska. This zone of low prices includes substantially the heaviest producing sections of all the great corn States. It embraces the greatest agricultural region within the United States, with highest land values, highest aggregate value of all crops and live stock produced. The minimum price of 45 cents a bushel appears at its northwestern corner, within an irregular square formed by adjacent portions of Iowa, Nebraska, South Dakota, and Minnesota.

In this region of minimum farmers' price occurs the lowest price depression, away from which prices graduate upward in every direction, attaining, as a rule, steadily higher levels toward all points of the compass. The maximum prices prevail in the arid Southwest, for the small quantities produced in the irrigated areas. Second only to those of this region are the high prices prevailing for corn in the Southeast and around the Gulf of Mexico. Very high price levels are as a rule attained near the seacoasts.

A varying degree of increase may be noted in the upward graduations, moving away from the described pivotal area of minimum price. Due eastward, throughout a large part of the corn States, bounded on the south by the Ohio River, prices are marked by comparative uniformity and rise only slightly; but when the Eastern States are reached the increases become more pronounced. Toward the West, where regions of scant production are not far distant from the pivotal area, prices ascend rapidly. Likewise the increases are more notable in all directions other than immediately eastward through the corn belt.

PRICE LEVELS AND COMMERCIAL MOVEMENT OF CORN.

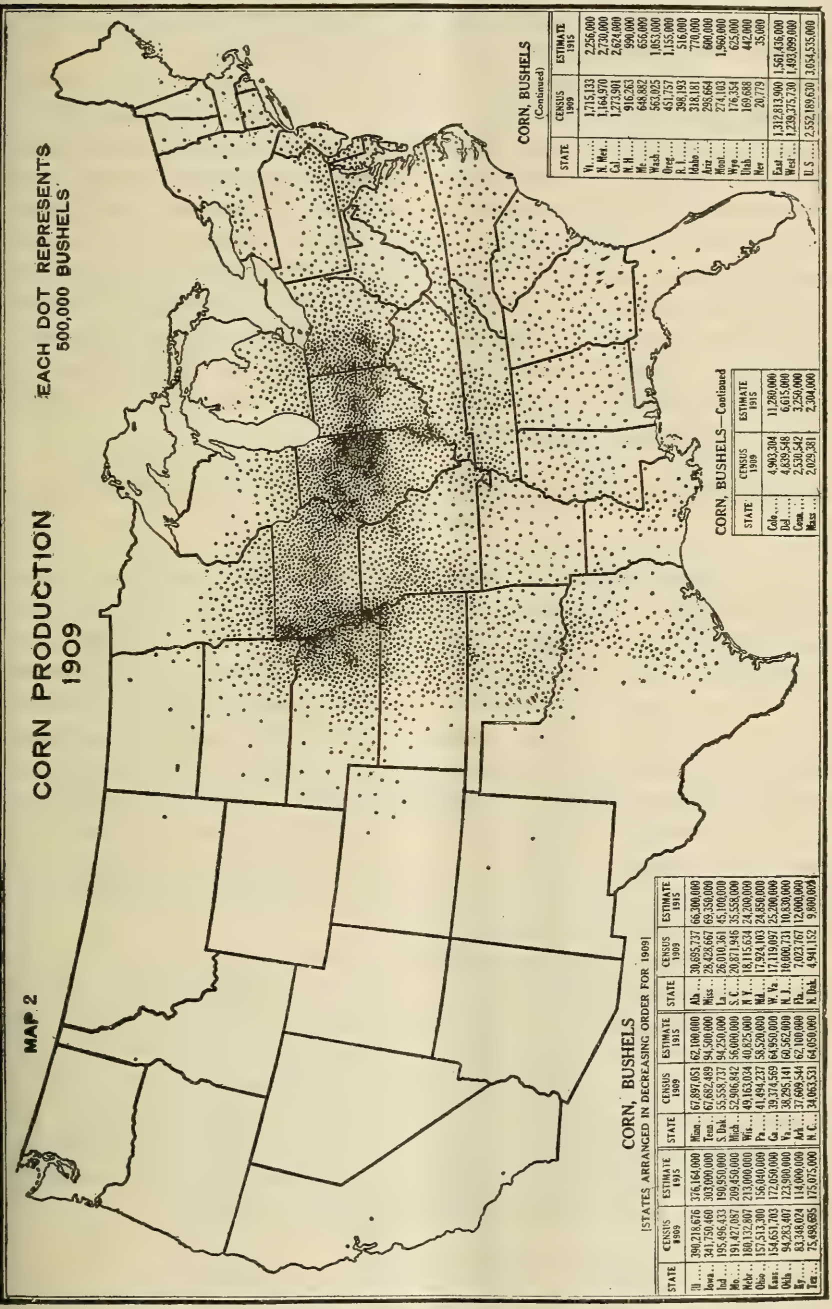
Practically the entire domestic surplus, as well as nearly all the corn entering into general trade channels, originates within the area of low prices.

The lowest price is found in that part of the surplus-producing region which is at greatest expense in reaching foreign and domestic markets.

Farm prices rise in all directions, following the course of corn from the territories of surplus to those of deficient production.

The geographic trend in the price levels of wheat affords an illuminating comparison. The general level of American wheat prices is to a considerable degree influenced by the price received for the surplus or export wheat, which during the past 10 years constituted from 11 to 37 per cent of the production. Lowest prices for wheat are paid to farmers in the surplus-producing areas most distant from the important foreign and domestic markets—in the Northwest. The highest farm prices are found in the sections of deficient production which are farthest removed from the surplus-growing areas—in the Southeast. Prices rise in the direction of the trade currents to markets or territories of insufficient production; and these currents vary with each crop, according to the location of producing and consuming region, and according to its uses, characteristics, and distributive movement.

In like manner the farmers' price of corn may be seen in Map 1 to rise steadily in a broad general relation to the trade channels from exporting to importing sections. Widely diffused east of the Great Plains (see Map 2), and becoming by far the most important crop in acreage and aggregate value, corn production is yet concentrated within a relatively small area of dense production in the prairie region of the North Central section. This area comprises parts of nine States and forms a triangular section whose base may be seen in the eastern parts of Kansas, Nebraska, and South Dakota, and its apex in western Ohio. Not only does this region produce the major part of the national crop, but it contributes also nearly all the corn which enters into general avenues of trade as well as practi-



CORN, BUSHELS

[STATES ARRANGED IN DECREASING ORDER FOR 1909]

STATE	CENSUS 1909	ESTIMATE 1915	STATE	CENSUS 1909	ESTIMATE 1915	STATE	CENSUS 1909	ESTIMATE 1915
Ill.	390,218,676	376,164,000	Minn. . .	67,897,051	62,100,000	Ala. . . .	30,695,737	66,300,000
Iowa. . .	341,750,460	303,000,000	Tenn. . .	67,682,489	94,500,000	Miss . . .	28,428,667	69,350,000
Ind	195,496,433	190,950,000	S. Dak. .	55,558,737	94,250,000	La.	26,010,361	45,100,000
Mo.	191,427,087	209,450,000	Mich . . .	52,906,842	56,000,000	S. C. . . .	20,871,946	35,558,000
Nebr . . .	180,132,807	213,000,000	Wis. . . .	49,163,034	40,825,000	N. Y. . . .	18,115,634	24,200,000
Ohio . . .	157,513,300	156,040,000	Pa.	41,494,237	58,520,000	Md. . . .	17,924,103	24,850,000
Kans. . .	154,651,703	172,050,000	Ga.	39,374,569	64,950,000	W. Va. .	17,119,097	25,200,000
Okla. . .	94,283,407	123,900,000	Va.	38,295,141	60,562,000	N. J. . . .	10,000,731	10,830,000
Ky.	83,348,024	114,000,000	Ark. . . .	37,609,544	62,100,000	Fla. . . .	7,023,767	12,000,000
Tex. . . .	75,498,695	175,075,000	N. C. . .	34,063,531	64,050,000	N. Dak.	4,941,152	9,800,000

CORN, BUSHELS—Continued

STATE	CENSUS 1909	ESTIMATE 1915
Colo.	4,903,304	11,280,000
Del.	4,839,548	6,615,000
Conn. . . .	2,530,542	3,250,000
Mass . . .	2,029,381	2,304,000

CORN, BUSHELS
(Continued)

STATE	CENSUS 1909	ESTIMATE 1915
Vt.	1,715,133	2,256,000
N. Mex. .	1,164,970	2,730,000
Cal.	1,273,901	2,624,000
N. H. . . .	916,263	990,000
Me.	648,882	656,000
Wash. . .	563,025	1,053,000
Oreg. . . .	451,757	1,155,000
R. I.	398,193	516,000
Idaho . . .	318,181	770,000
Ariz.	298,664	600,000
Mont. . . .	274,103	1,960,000
Wyo. . . .	176,354	625,000
Utah. . . .	169,688	442,000
Nev	20,779	35,000
East. . . .	1,312,813,900	1,561,436,000
West . . .	1,239,375,730	1,493,099,000
U. S. . . .	2,552,189,630	3,054,535,000

MAP 2.—Distribution of corn production, 1909 (U. S. Bureau of the Census).

cally the entire gross surplus of the country. All other sections produce less than their requirements. In the Great Plains and westward—nearly half the total land area—hardly 2 per cent of the national harvest is produced.

While low price levels rule throughout the surplus-producing area, cheapest corn has been observed within its northwestern corner. This part is most disadvantageously situated with regard to the important domestic and foreign markets, which lie to the East and South. From the centrally located corn belt the product moves to practically all points of the compass, since all other sections must supplement local crops by shipments from this territory. Likewise, prices mount in the direction of this flow, attaining steadily higher levels toward the areas which (subject to the modifications of local conditions) are most distant from the regions of surplus corn. Distance or length of haul in this sense is taken to represent differences in transportation costs, in which it is ordinarily the chief factor. Other items of distributive expense are usually measured in fractions of a cent per bushel, and vary but little with distance.

PREDOMINANT TRADE ROUTES AND PRICE LEVELS, AND LOCAL VARIATION.

In the prevailing drift of the price levels a considerable degree of local variation may be seen. Such differences, which are to some extent observable on Map 1, are shown more clearly in a later detailed map. Thus the upgrade—from the pivotal area of lowest price in the corn belt—is slower in some directions than in others. It is slower throughout the sections where the traffic moves in greatest volume or where large local supplies are available—eastward across the North Central States; the upgrade becomes more rapid through regions of scant production or of relatively little consumption—westward, for instance. Aside from this irregular increase, many areas appear wherein prices paid to farmers are considerably higher or lower than in the surrounding regions.

The manifold uses of grain, plant and cob, as well as the conditions surrounding the distribution of the corn crop, result in a somewhat intricate commercial and price movement. To account for the drift of the price levels it is necessary to consider, briefly, a few international as well as domestic phases of the commerce in corn. To account for local variations it is necessary to consider such local factors as differences in costs of transportation by wagon, rail or water, rural roads, accessibility of markets, the volume and organization of the traffic as shown in elevating, and market facilities.

GENERAL FEATURES OF CORN DISTRIBUTION.

The United States produces more than twice as much corn as the rest of the world combined, but consumes practically its entire crop. Its share of the foreign commerce in corn is relatively insignificant.

Available foreign supplies are small, hence diminished consumption, and not international supply, regulates prices in years of domestic shortage.

AMERICAN CORN IN RELATION TO FOREIGN MARKETS.

Except in years of domestic shortage, the general level of American farm prices of corn is to some extent influenced by the prices prevailing at importing European markets, though to a much less marked degree than in the case of wheat, because of the lesser importance of corn exports. There exists, moreover, a degree of interrelation between corn, wheat, and rye prices.

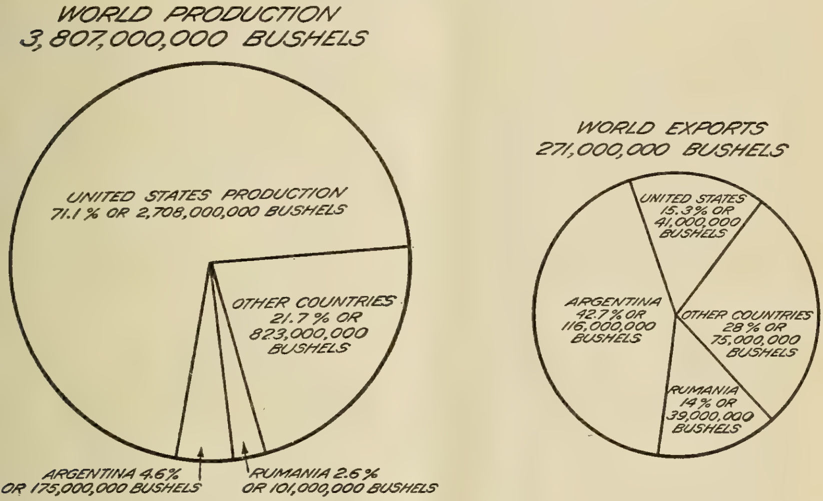


FIG. 1.—Corn: World production and commerce. Figures are averages for the five years 1909–1913, the latest available data showing usual conditions. They relate to all countries for which data are available, and represent, substantially, world production and exports.

The United States ordinarily produces over 70 per cent of the world's corn, more than twice the production of the rest of the world combined; yet our exports seldom exceed 1½ per cent of the domestic production. They averaged in 1909–1913 only about 15 per cent of he world's exports. On the other hand, Argentina, whose average crop is about one-sixteenth that of the United States, contributes nearly three times as much as the latter to the world commerce in corn—42 per cent of the total exports, or over half of its harvest. Practically all corn exports go to Europe.

Domestic consumption evidently absorbs practically the entire harvest of the United States. But even in our internal commerce only about a fifth of the corn produced enters into trade channels. It is customary to say that the domestic corn is "marketed on the hoof," that the price of the United States corn crop affects the meat markets of the world, rather than the international prices of grain. The total consumption for human food, industrial uses and the feeding of work animals represents only a small share of the crop. Foreign harvests and prices do not enter as a regulating factor in years of domestic shortage since only relatively small foreign supplies are available. A surplus in adjoining countries would ordinarily have an effect upon domestic prices, as in the case of Canadian wheat and oats, but Canada and Mexico import corn from the United States.

DOMESTIC DEMAND AND CONSUMPTION VARIABLE.

The high degree of elasticity in the quantities of corn consumed is a notable feature of its use. The annual variation in the United States consumption for the six years 1911 to 1916 ranged, roughly, from 200,000,000 to 700,000,000 bushels. This fact is suggestive when considered in connection with the comparatively stable demand for other farm products, such as wheat or cotton, under normal conditions. Market prices, not only of corn but of live stock and live-stock products, govern the extent to which corn is fed to live stock, is used for human consumption within the United States, or is exported. The prices of other feeds enter also herein. The quantity fed to live stock (about three-fourths of the total production) varies greatly according to market conditions affecting each class of stock, and the quality of the crop. Especially is this true with regard to swine, whose yearly consumption averages about 7,000,000 bushels, and the number of which varies from year to year. High prices or a poor quality of corn result, in their first effect, in an unloading of hogs upon the market. The quantity used for industrial purposes is relatively stable, but represents a small fraction of the production.

The relative consumption in one section compared with another also varies greatly. By States, the per capita production varies from less than 1 bushel to 159 bushels. The per capita consumption for all purposes varies almost as widely. An average of nearly one and one-quarter billion bushels, or a little less than half the total production, is consumed in the North Central States for feeding purposes alone. Comparatively trifling quantities are consumed west of the corn belt. In general, outside of the corn States, a much smaller proportion is devoted to feeding purposes, because of deficient supply and relatively high price.

STATISTICS: DISPOSITION OF AMERICAN CORN CROP.

Over four-fifths of the crop is consumed on farms; only one-fifth enters into general trade channels, part of which is shipped again to farms.

About one-sixth of the crop is consumed in cities for industrial and other purposes.

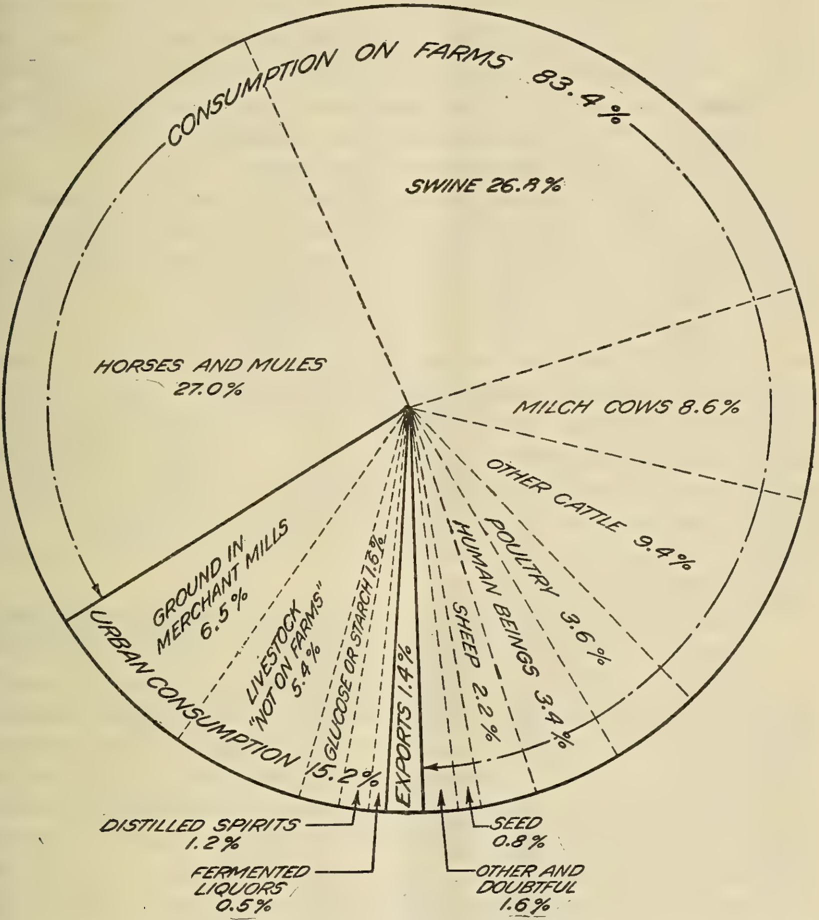


FIG. 2.—Approximate disposition of the United States corn crop.

In Table 1 data have been assembled which bear upon factors mentioned in the preceding paragraphs. Only about 82 per cent of the crop, on an average, is of merchantable quality. The quantity shipped out of the counties where grown, constituting in 1911–1915 only 19.4 per cent of the aggregate production of the United States, may be said to represent the corn moving into general trade channels; in round numbers, only one-half billion out of the two and three-quarter billion bushels. The balance remaining in the counties where grown, 80.6 per cent, consists principally of the corn consumed on farms where it is produced, and a small percentage of sales to local feeders and local markets. The major part of the crop never leaves the farms on which it is raised. The census for 1909 reported 23 per cent of the corn crop as having been sold. In that year, therefore, 77 per cent of the corn grown was retained on the farms where it was produced. This fraction includes the soft and unmerchantable corn. In the same year (1909) 18 per cent of the total harvest was shipped out of counties where grown; thus the difference between this 18 per cent and the 23 per cent sold off the farms represents local sales, or corn sold but not shipped out of counties where grown. This amounted in that year to but 5 per cent.

The farm consumption approximates 83.4 per cent; it consists of the small fraction constituted by corn shipped from markets and farms to farms, and, chiefly, of the home-grown product. Horses and mules, as one item, and swine, each absorb more than one-fourth of the total production, three-fourths of a billion bushels each. These items are highly variable, as stated, depending upon size of crop, costs of other feeds and market prices of live stock.

The urban consumption is more stable. The items in Table 1, listed under corn disposed of in cities, total only 16.6 per cent of the national production, or about a half billion bushels. To obtain aggregate urban receipts, there should be added some quantities reshipped from market to farms, which are included in this statement under farm consumption.

The largest item in city consumption consists of the corn ground in merchant flour mills (180 million bushels or 6.5 per cent of the crop). In the Census for the year 1909, 80 per cent of the corn entering such mills was reported to be "manufactured chiefly for human consumption," and 20 per cent, or 42 million bushels, "manufactured chiefly for live stock." Additional quantities enter small custom mills, no recent data for which are available; this appears, however, to be included in the estimates of farm use. In the Census of 1909 it was reported to be 35 million bushels. Quantities fed to live stock in cities are of some importance, constituting about 5.4 per cent of production. Industrial uses absorb many million bushels, but amount to only a small percentage of the crop. Excepting its use in the manufacture of hominy, industrial demands furnish a market for poorer qualities of corn.

TABLE 1.—*Corn: Approximate distribution of the United States crop.*

[Figures are averages for the 5 years 1911-1915, where not otherwise noted.]

	Percentage of production.	Bushels.
1. Production	100.0	2,766,000,000
2. Merchantable corn	82.4	2,279,000,000
3. Shipped out of counties where grown (represents commercial movement to other than local markets)[1]	19.4	536,000,000
4. Remaining in counties where grown (mostly farm consumption, also local sales)[1]	80.6	2,230,000,000
5. Approximate consumption on farms (substantially item 4, plus shipments to farms)	83.4	2,307,000,000
6. Urban consumption and exports	16.6	459,000,000
7. Surplus over farm consumption of all States having such a surplus	19.8	546,000,000
8. Deficiency, under farm demands, of corn-deficiency States (shipments from markets to farms, and local sales to farms)	3.2	87,000,000
Difference—urban consumption and exports (See Table 2A, p. 16.)	16.6	459,000,000

	Percentage of production.		Percentage of production.	Bushels.
Corn remaining in counties where grown (item 4)	80.6	**Approximate farm consumption** (item 5):[2]		
		Horses and mules	27.0	747,000,000
		Swine	26.8	741,000,000
		Milch cows	8.6	238,000,000
Gross deficiency of States whose production is under requirements for farm consumption (item 8)[1]	3.2	Other cattle	9.4	260,000,000
		Sheep	2.2	61,000,000
		Poultry	3.6	100,000,000
		Human beings	3.4	94,000,000
Total, approximately equal to total farm consumption	83.8	Seed	.8	22,000,000
		Other or doubtful	1.6	44,000,000
		Total consumed on farms	83.4	2,307,000,000
Shipped out of counties where grown (item 3)[1]	19.4	**Urban corn receipts and consumption** (chiefly item 3, also some shipments from farms in same county):		
Deduct shipments to farms (item 8)	3.2			
Balance, approximately equal to urban receipts and exports	16.2	Ground in merchant flour mills (chiefly for human consumption, also for feed, etc). census of 1914	6.5	180,000,000
		Used in manufacture of glucose or starch. Census of 1914	1.6	44,000,000
		Used in manufacture of distilled spirits, fiscal year ended June 30, 1915	1.2	32,000,000
		Used in manufacture of fermented liquors, fiscal year ended June 30, 1915	.5	14,000,000
		Exports	1.4	39,000,000
		Corn fed to live stock "not on farms," numbering (census of 1910): Horses, mules, asses, and burros, 3,470,000; dairy cows, 1,170,000; other cattle, 709,000; swine, 1,288,000; sheep, 391,000; goats, 115,000; estimated at	5.4	150,000,000
		Total of items enumerated[3]	16.6	459,000,000

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[1] These figures (items 3 and 4) show the gross movement and do not take into account the intrastate corn shipments between surplus and deficiency sections of the same State.

[2] Data regarding farm consumption are based upon investigations made by N. C. Murray, assistant statistician, Bureau of Crop Estimates.

[3] Additional quantities marketed in cities are reshipped to farms, and included in consumption on farms (above).

PRODUCTION, CONSUMPTION, AND COMMERCE, BY STATES AND SECTIONS.

The foregoing is indicative of a few general phases in the disposition of the corn crop. Data for production, marketing, consumption, and surplus, by geographic divisions, are shown in Tables 2 and 2A, and in figure 3.

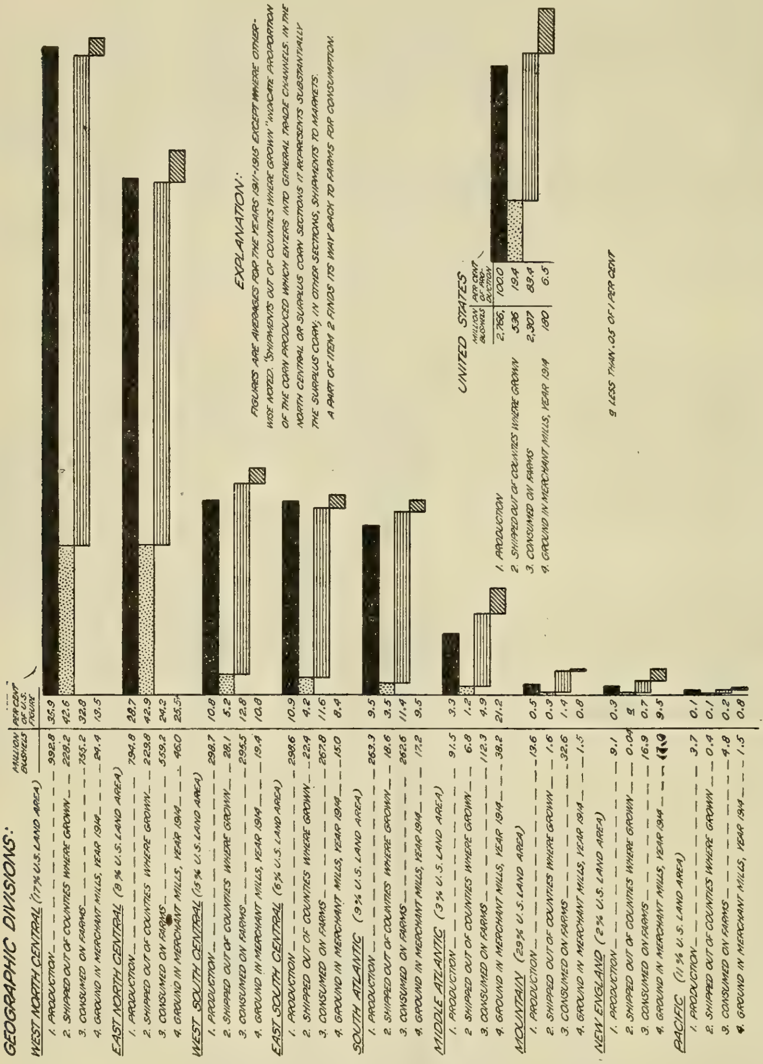

FIG. 3.—Corn: Geographic alignments of production in relation to consumption and trade movement.

The dominant share of the two North Central divisions in production, consumption, and commerce stands out in relief against the much smaller ratio of all items in the East and South, and the comparatively negligible quantities in the Mountain and Pacific

States. The East and South, however, draw the greater part of the corn shipments from the surplus-producing territory. In the Mountain and Pacific States the quantities produced and consumed are unimportant compared to the other sections, but the ratio of corn importation to production and the degree of deficiency are very high. Of the amount consumed on farms, about 57 per cent is apportioned to the North Central States, 35 per cent to the South, and 6 per cent to the North Atlantic States.

As indicated by figure 3, the North Central States, which comprise about 25 per cent of the total land area and less than a third of the total population, produce about 65 per cent of the crop, and consume on farms alone about three-fourths of the production of the two groups, or about half of the national crop. This section is first in the aggregate value of all live stock produced. After deducting the heavy local consumption, the remaining surplus, which is only about a fourth of the production of the two groups, still constitutes nearly seven-eighths of the amount entering trade channels. Of the 12 States in these two divisions only 7 produce a surplus; the northern 5 import considerable quantities. These "seven corn-surplus States," so called, ranked as to amount of surplus in 1911–1915, are: Illinois, Iowa, Indiana, Nebraska, Missouri, Ohio, and Kansas.

The South contains about 40 per cent of all land in farms in the United States and produced in 1911–1915 30 per cent of the corn crop. Practically the entire production is consumed locally, very little entering into trade channels. Total requirements for consumption on farms, live stock in cities, mills, and industrial uses bring large quantities southward. It is well known that corn to some extent takes the place of wheat for food purposes throughout the greater part of the South. While cheaper than wheat, corn prices usually about equal the ordinary prices of wheat in the States to the North. High and irregular price levels prevail. Local conditions and the character of the distributive machinery make for irregularity in the price zones. The highest degree of corn deficiency in the South obtains in its most southern States, and the high prices prevailing there preclude extensive use for feeding purposes. The major part is grown in the northern tier of States.

The largest movement of corn is directed toward the North Atlantic States—the comparatively densely populated industrial section. Only a very small fraction of the corn produced in these States enters trade channels. As the farm consumption is considerably in excess of production, shipments are sent here for this use as well as to fill urban requirements. An amount equal to half of production, and in most of the States largely in excess of production, passes through merchant mills alone. The deficit under combined requirements for farms and merchant mills is approximately 85 million bushels. The cities draw additional quantities for live stock and for export.

Mountain and Pacific divisions consume but 2 per cent of the national production, but even this consumption is several times the amount grown. Corn generally equals or exceeds wheat in price in these States. The percentage grown which is of merchantable quality is comparatively low.

TABLE 2.—*Corn: Geographic alignments—production, commercial movement and consumption.*

[Figures are yearly averages for 1911 to 1915, unless otherwise noted.]

States and geographic divisions.	Production.		Merchantable corn.		Shipped out of counties where grown (substantially the commercial movement).		Approximate consumption on farms and in merchant mills.		Approximate surplus or deficiency over consumption on farms and in merchant flour mills.[1]		Relative importance of States and sections.			
	Quantity.	Per capita.	Quantity.	Percentage of production.	Quantity.	Percentage of production.	Quantity.	Fraction of United States production.	Surplus.	Deficiency.	In production.	In shipments out of counties where grown.	In quantities consumed on farms.	In quantities ground in merchant mills.[1]
	Bush. (000 omitted).	*Bushels.*	*Bush. (000 omitted).*	*Per cent.*	*Bush. (000 omitted).*	*Per cent.*	*Bush. (000 omitted).*	*Per cent.*	*Bush. (000 omitted).*	*Bush. (000 omitted).*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
United States	2,766,112	28.5	2,279,298	82.4	535,953	19.4	2,487,116	89.9	278,996	....	100.0	100.0	100.0	100.0
New England	9,059	1.3	6,895	76.1	36	.4	33,948	1.2	....	24,889	.3	(2)	.7	9.5
Middle Atlantic	91,522	4.4	75,358	82.3	6,759	7.4	150,451	5.5	....	58,929	3.3	1.2	4.9	21.2
South Atlantic	263,312	20.6	215,981	82.0	18,647	7.1	279,769	10.1	....	16,457	9.5	3.5	11.4	9.5
East North Central	794,838	41.9	662,003	83.3	229,788	28.9	605,178	21.9	189,660	....	28.7	42.9	24.2	25.5
West North Central	992,756	82.3	843,761	85.0	228,157	23.0	779,679	28.2	213,077	....	35.9	42.6	32.8	13.5
East South Central	298,611	34.4	243,273	81.5	22,435	7.5	282,856	10.2	15,755	....	10.9	4.2	11.6	8.4
West South Central	298,651	31.4	219,556	73.5	28,141	9.4	314,864	11.4	....	16,213	10.8	5.2	12.8	10.8
Mountain	13,632	4.6	9,576	70.2	1,583	11.6	34,116	1.2	....	20,484	.5	.3	1.4	.8
Pacific	3,731	.8	2,895	77.6	407	10.9	6,255	.2	....	2,524	.1	.1	.2	.8
New England:														
Maine	686	.9	559	81.5	6	.9	5,499	.2	....	4,813	(2)	(2)	(2)	....
New Hampshire	973	2.2	735	75.5	1	.1	4,308	.2	....	3,335	(2)	(2)	.1	....
Vermont	1,944	5.4	1,340	68.9	....	(2)	6,300	.2	....	4,356	.1	(2)	.1	....
Massachusetts	2,137	.6	1,638	76.6	4	.2	7,642	.3	....	5,505	.1	(2)	.2	....
Rhode Island	466	.8	359	76.8	7	1.5	1,415	(2)	....	949	(2)	(2)	(2)	....
Connecticut	2,853	2.4	2,264	79.4	18	.6	8,784	.3	....	5,931	.1	(2)	.3	....
Middle Atlantic:														
New York	20,388	2.1	14,329	70.3	359	1.8	52,165	1.9	....	31,777	.7	(2)	1.4	....
New Jersey	10,495	3.8	9,082	86.5	1,426	13.6	18,447	.7	....	7,952	.4	.3	.7	....
Pennsylvania	60,639	7.5	51,947	85.7	4,974	8.2	79,839	2.9	....	19,200	2.2	.9	2.8	....
South Atlantic:														
Delaware	6,635	31.9	5,663	85.4	2,147	32.4	4,999	.2	1,636	....	.2	.4	.2	....
Maryland	24,080	18.1	19,728	81.9	5,651	23.5	21,110	.8	2,970	....	.9	1.0	.9	....
Virginia	49,292	23.2	38,826	78.8	4,323	8.8	49,927	1.8	....	635	1.8	.8	1.9	....
West Virginia	22,652	17.3	16,716	73.8	919	4.1	27,500	1.0	....	4,848	.8	.2	1.1	....
North Carolina	55,534	24.1	45,532	82.0	2,083	3.8	54,238	1.9	1,296	....	2.0	.4	2.2	....
South Carolina	35,493	22.6	31,310	88.2	982	2.8	42,567	1.5	....	7,074	1.3	.2	1.8	....

Florida	10,225	12.4	8,077	79.0	360	3.5	15,962	.6	....	5,737	.4	.1	.7	....
East North Central:														
Ohio	153,991	31.0	124,643	80.9	35,356	23.0	128,245	4.6	25,746	....	5.6	6.6	5.1	....
Indiana	180,926	65.5	151,015	83.5	53,438	29.5	136,953	5.0	43,973	....	6.5	10.0	5.3	....
Illinois	343,924	58.3	295,980	86.1	136,452	39.7	209,757	7.6	134,167	....	12.4	25.5	8.7	....
Michigan	57,226	19.5	43,424	75.9	2,652	4.6	65,195	2.4	....	7,969	2.1	.5	2.6	....
Wisconsin	58,771	24.3	46,941	79.9	1,890	3.2	65,028	2.3	....	6,257	2.1	.3	2.5	....
West North Central:														
Minnesota	80,283	36.8	65,374	81.4	14,211	17.7	75,993	2.7	4,290	....	2.9	2.7	3.2	....
Iowa	353,619	159.1	330,608	93.5	102,568	29.0	230,044	8.3	123,575	....	12.8	19.1	9.8	....
Missouri	186,643	55.6	148,353	79.5	17,323	9.3	159,532	5.8	27,111	....	6.7	3.2	6.6	....
North Dakota	10,121	15.3	5,824	57.5	218	2.2	13,556	.5	....	3,435	.4	(2)	.6	....
South Dakota	73,347	114.1	53,978	73.6	22,726	31.0	60,054	2.2	13,293	....	2.6	4.3	2.6	....
Nebraska	167,928	136.2	142,589	84.9	45,936	27.4	126,548	4.6	41,380	....	6.1	8.6	5.4	....
Kansas	120,815	68.5	97,035	80.3	25,175	20.8	113,952	4.1	6,863	....	4.4	4.7	4.6	....
East South Central:														
Kentucky	96,623	41.4	73,666	76.2	6,585	6.8	85,160	3.1	11,463	....	3.5	1.2	3.5	....
Tennessee	84,599	37.8	71,748	84.8	11,551	13.7	77,123	2.8	7,476	....	3.1	2.2	3.0	....
Alabama	57,066	25.5	47,230	82.8	1,891	3.3	58,526	2.1	....	1,460	2.1	.4	2.4	....
Mississippi	60,323	32.1	50,629	83.9	2,408	4.0	62,047	2.2	....	1,724	2.2	.4	2.7	....
West South Central:														
Louisiana	38,258	21.9	31,098	81.3	3,050	8.0	39,097	1.4	....	839	1.4	.5	1.7	....
Texas	137,145	32.9	99,834	72.8	8,964	6.5	162,426	5.9	....	25,281	5.0	1.7	6.7	....
Oklahoma	72,983	37.6	47,458	65.0	14,395	19.7	62,377	2.3	10,606	....	2.6	2.7	2.4	....
Arkansas	50,265	30.3	41,166	81.9	1,732	3.4	50,964	1.8	....	699	1.8	.3	2.0	....
Mountain:														
Montana	1,077	2.6	594	55.2	24	2.2	5,906	.2	....	4,829	.1	(2)	.3	....
Wyoming	441	2.7	237	53.7	4	.9	4,221	.2	....	3,780	(2)	(2)	.2	....
Colorado	8,433	9.6	6,056	71.8	1,280	15.2	18,467	.7	....	10,034	.3	.2	.7	....
New Mexico	2,257	6.1	1,652	73.2	220	9.7	3,226	.1	....	969	.1	(2)	.1	....
Arizona	535	2.3	428	80.0	32	6.0	1,009	(2)	....	474	(2)	(2)	(2)	....
Utah	350	.9	232	66.3	9	2.6	436	(2)	....	86	(2)	(2)	(2)	....
Nevada	33	.3	27	81.8	....	(2)	100	(2)	....	67	(2)	(2)	(2)	....
Idaho	506	1.3	350	69.2	14	2.8	751	(2)	....	245	(2)	(2)	(2)	....
Pacific:														
Washington	936	.7	712	76.1	43	4.6	1,975	.1	....	1,039	(2)	(2)	.1	....
Oregon	723	1.0	464	64.2	11	1.5	949	(2)	....	226	(2)	(2)	(2)	....
California	2,072	.8	1,719	83.0	353	17.0	3,331	.1	....	1,259	.1	.1	.1	....
United States	2,766,112	28.5	2,279,298	82.4	535,953	19.4	2,487,116	89.9	[3] 455,845	[3] 176,849	100.0	100.0	100.0	....
Domestic exports (including equivalent of corn meal)	....	....	....	....	....	....	....	....	39,000	....	....	....	....	....

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[1] Figures for corn ground in merchant flour mills are from the Census of 1914.

[2] Less than one-tenth of 1 per cent.

[3] Gross surplus and deficiency.

TABLE 2A.—*Corn: Production, consumption on farms and in merchant mills; surplus and deficiency.*

[Figures are yearly averages for 1911–1915, unless otherwise noted.]

State or geographic division.	Production.	Ground in merchant mills, 1914 census.	Consumed on farms (approximate).			Surplus or deficit over consumption on farms only.	
			Quantity.	Per cent of production.	Per cent of United States production.	Surplus.	Deficit.
	Thousand bushels.		*Thousand bushels.*	*Per cent.*	*Per cent.*	*Thousand bushels.*	
United States	**2.766.112**	**180,116**	**2,307,000**	**83.4**	**83.4**	[1] **459,112**	....
New England	9,059	17,048	16,900	187.0	.6	....	7,841
Middle Atlantic	91,522	38,151	112,300	123.0	4.0	....	20,778
South Atlantic	263,312	17,169	262,600	100.0	9.5	712	....
East North Central	794,838	45,978	559,200	70.0	20.2	235,638	....
West North Central	992,756	24,379	755,300	76.0	27.3	237,456	....
East South Central	298,611	15,056	267,800	90.0	9.7	30,811	....
West South Central	298,651	19,365	295,500	99.0	10.7	3,151	....
Mountain	13,632	1,515	32,600	239.0	1.2	....	18,968
Pacific	3,731	1,455	4,800	129.0	.2	....	1,069
New England:							
Maine	686	4,199	1,300	190.0	.1	....	614
New Hampshire	973	2,208	2,100	216.0	.1	....	1,127
Vermont	1,944	3,800	2,500	129.0	.1	....	556
Massachusetts	2,137	4,042	3,600	168.0	.1	....	1,463
Rhode Island	466	815	600	129.0	(2)	....	134
Connecticut	2,853	1,984	6,800	238.0	.2	....	3,947
Middle Atlantic:							
New York	20,388	21,065	31,100	153.0	1.1	....	10,712
New Jersey	10,495	2,447	16,000	152.0	.6	....	5,505
Pennsylvania	60,639	14,639	65,200	108.0	2.3	....	4,561
South Atlantic:							
Delaware	6,635	499	4,500	68.0	.2	2,135	....
Maryland	24,080	1,610	19,500	81.0	.7	4,580	....
Virginia	49,292	5,127	44,800	91.0	1.6	4,492	....
West Virginia	22,652	3,300	24,200	107.0	.9	....	1,548
North Carolina	55,534	2,538	51,700	93.0	1.9	3,834	....
South Carolina	35,493	267	42,300	119.0	1.5	....	6,807
Georgia	59,401	3,666	59,800	101.0	2.1	....	399
Florida	10,225	162	15,800	155.0	.6	....	5,575
East North Central:							
Ohio	153,991	9,545	118,700	77.0	4.3	35,291	....
Indiana	180,926	14,053	122,900	68.0	4.4	58,026	....
Illinois	343,924	10,257	199,500	58.0	7.2	144,424	....
Michigan	57,226	5,395	59,800	104.0	2.2	....	2,574
Wisconsin	58,771	6,728	58,300	99.0	2.1	471	....
West North Central:							
Minnesota	80,283	3,093	72,900	91.0	2.6	7,383	....
Iowa	353,619	3,344	226,700	64.0	8.2	126,919	....
Missouri	186,643	8,532	151,000	81.0	5.4	35,643	....
North Dakota	10,121	56	13,500	133.0	.5	....	3,379
South Dakota	73,347	154	59,900	82.0	2.2	13,447	....
Nebraska	167,928	2,248	124,300	74.0	4.5	43,628	....
Kansas	120,815	6,952	107,000	88.0	3.9	13,815	....
East South Central:							
Kentucky	96,623	4,760	80,400	83.0	2.9	16,223	....
Tennessee	84,599	8,023	69,100	82.0	2.5	15,499	....
Alabama	57,066	1,926	56,600	99.0	2.1	466	....
Mississippi	60,323	347	61,700	102.0	2.2	....	1,377
West South Central:							
Louisiana	38,258	597	38,500	101.0	1.4	....	242
Texas	137,145	8,627	153,800	112.0	5.6	....	16,655
Oklahoma	72,983	5,577	56,800	78.0	2.0	16,183	....
Arkansas	50,265	4,564	46,400	92.0	1.7	3,865	....
Mountain:							
Montana	1,077	6	5,900	548.0	.2	....	4,823
Wyoming	441	21	4,200	952.0	.2	....	3,759
Colorado	8,433	1,367	17,100	203.0	.6	....	8,667
New Mexico	2,257	26	3,200	142.0	.1	....	943
Arizona	535	9	1,000	187.0	(2)	....	465
Utah	350	35	400	114.0	(2)	....	50
Nevada	33	....	100	303.0	(2)	....	67
Idaho	506	51	700	138.0	(2)	....	194
Pacific:							
Washington	936	475	1,500	160.0	.1	....	564
Oregon	723	49	900	124.0	(2)	....	177
California	2,072	931	2,400	116.0	.1	....	328
United States	2,766,112	180,116	2,307,000	83.4	83.4	546,334	87,212

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[1] Net surplus over average farm consumption.

[2] Less than one-tenth of 1 per cent.

Data regarding farm consumption are based upon unpublished investigations made by N. C. Murray, Assistant Statistician, Bureau of Crop Estimates.

A brief analysis of the salient features of Tables 2 and 2A, by geographic sections, follows:

West North Central States.—This division leads in corn production with 35.9 per cent of the total; contains 17 per cent of the total land area and 13 per cent of the population. It is, however, second to the eastern division of the North Central States in the quantity, as well as in the percentage, of the crop which moves to markets. Freight rates on corn to the Atlantic seaboard or to the South are higher from the corn States west of the Mississippi. This places those States at a disadvantage in selling either for export or to important domestic markets, and consequently encourages in these western States the feeding of corn to live stock and the production of meat. Prices are lowest in this group. It ranks first in live-stock production and quantities consumed on farms. The per capita production ranges from 15 to 159 bushels, by States. The section is only third in the quantity of corn ground in merchant mills. Out of its seven States the three farthest north, North Dakota, South Dakota, and Minnesota, do not usually produce a surplus. Here higher prices prevail, increasing with distances from the area of surplus.

East North Central States.—Second in point of production, this division shipped in the five years under consideration the largest quantity and highest percentage out of counties where grown (42.9 per cent). Prices here are higher than in the corn States to the west, but lower than in other sections. A strategic position at the head of the Great Lakes, between the Ohio and Mississippi Rivers, with cheap water transportation and nearness to corn-deficiency States, gives this division more favorable conditions with regard to markets. It ships out a larger share of its crop than the corn States west of the Mississippi and feeds lesser proportions. This division is first in the quantities consumed by merchant flour mills. It is more densely populated than the western corn States, and its per capita production ranges from 20 to 66 bushels. In Michigan and Wisconsin, however, where production is less than consumption, prices are higher than in other States of this division.

South Central States.—The east and west south central divisions are about equal as to quantities produced; together they raise a fifth of the United States crop. Three out of the 16 States—Kentucky, Tennessee, and Texas—produce the major part of the crop of this group of States. The general conditions pointed out in the discussion of the Southern States with regard to corn deficiency and prices prevail here.

South Atlantic States.—In production, this section measured about 10 per cent of the national total. The three northern States (Delaware, Maryland, and Virginia) contributed about 65 per cent of the quantity entering trade channels from this group of States. The deficit under combined requirements of farms and merchant mills is around 16 million bushels; to this should be added demands for urban consumption and industrial uses, as well as the movement to the seaports for export. Farm prices of corn in the more southern States of this section are higher than in most other States except in the far southwest. The same general conditions obtain as were indicated for the entire southern group.

Middle Atlantic States.—Containing 3 per cent of the total land area and leading in point of population (21 per cent), this section produces only 3 per cent of the national corn. Here farm uses absorb substantially the entire local production, which is less than needs even for this purpose. It ranks second as to quantities ground in merchant mills. To requirements for the latter, which swell the volume of shipments to this group by 59 million bushels, should be added about 10 million bushels more, on an average, moving to the seaports for export, also the requirements for urban consumption.

New England States.—The greatest relative deficiency of corn prevails in this section. Although production of other cereals has declined rapidly in these States, corn has retained its place. Local production is less than 1 per cent of the national crop and is consumed almost entirely on the farms. The farm consumption alone is about twice the local production. New England merchant flour mills receive about 17 million bushels of corn, or double the production of the division, but only about a half-million bushels of wheat. Seaports draw some additional quantities for export. A total of 81 glucose and starch factories, with an aggregate consumption of 40 million bushels of corn, were reported by the 1914 census. Of such factories, 51 were found in Maine alone and 58 in all in the entire division. Within recent years Argentine corn, to the amount of several million bushels annually, has been imported into this section for industrial uses.

Mountain States.—Colorado produces 60 per cent of the corn raised in these eight States, whose production constitutes only one-half of 1 per cent of the national crop. The figures indicate a flow of several million bushels westward for consumption, but in proportion to demands of other sections such shipments are unimportant. Corn as a rule exceeds wheat in price throughout a large part of this group. In its southwestern part the highest corn prices in the United States are found.

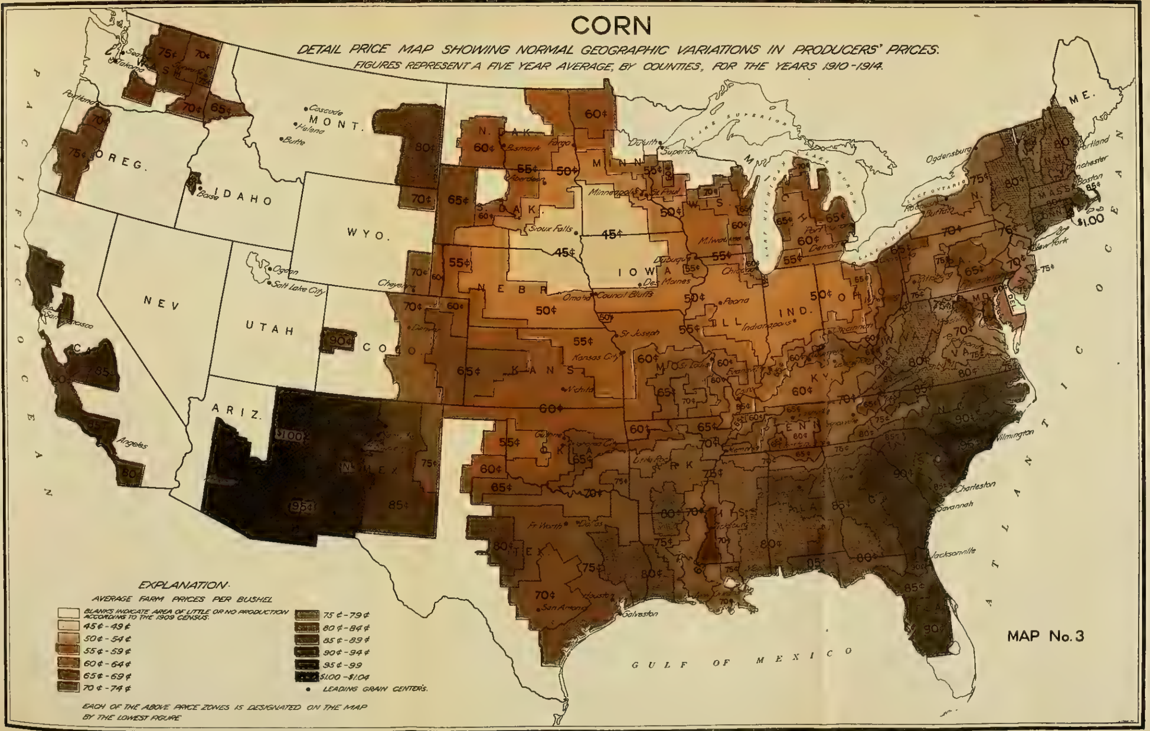
Pacific States.—Barley takes the place of corn in the Pacific division for feeding purposes and rice, to some extent, for brewing. Production and consumption are lowest here. Transportation expense from the distant corn-surplus States almost precludes its use, except in comparatively small quantities for industrial purposes. High prices prevail for the small quantity grown.

Details appear in Tables 2 and 2A. Figures of consumption on farms are approximate only. They should be regarded as showing in a general way the geographic alignments and are a rough measurement, particularly useful in showing the relative position of States and sections as to surplus or deficiency. With respect to shipments out of counties where grown, the figures should be regarded as indicating the corn moving into general trade channels. They do not usually indicate the surplus of a State because of intrastate shipments from counties producing surplus to those producing insufficient corn.

DETAIL PRICE MAP AND LOCAL PRICE FACTORS.

In map No. 3 the geographic variation in farm prices of corn has been shown in greater detail. This map is based on the same data as map No. 1, but a 5-cent price unit has been used (instead of 10 cents) to throw into relief local differences. A smaller unit has not appeared feasible, because of the irregularity of minor fluctuations, due to such causes as local harvest conditions and the quality of the crop.

Subordinate to the general trend of the price levels which have already been outlined, much local price variation is observable on this map. Prices rise more rapidly and irregularly in some directions, particularly in areas of insufficient production. A difference in price between sections of the same State amounting to at least 15 cents a bushel, may be seen in most States. The difference in corn prices between parts of Missouri, as an instance in point, is greater than the



CORN

DETAIL PRICE MAP SHOWING NORMAL GEOGRAPHIC VARIATIONS IN PRODUCERS' PRICES.
FIGURES REPRESENT A FIVE YEAR AVERAGE, BY COUNTIES, FOR THE YEARS 1910-1914.

THE NORRIS PETERS CO., WASHINGTON, D. C.

normal cost of shipping from St. Louis to some European markets. Considerable unevenness in the price levels occurs throughout the Appalachian and other mountainous regions and in general throughout the South. Corn prices in the Ozark Mountain section in Missouri are higher than in the surrounding territory.

CITY AND FARM CONSUMPTION CONTRASTED.

In the trade channels of corn two distinct currents are apparent, each having a direct bearing upon the irregularities in the slope of the price levels. One relates to the farm consumption—of home-grown corn as well as of smaller quantities shipped in, the other to the movement to cities, either for concentration and reshipment or for consumption.

In the farm consumption such factors as availability of transportation facilities, condition of roads, length of hauls, and lack of marketing organization exert a marked influence on the price levels. The quantities of corn absorbed locally vary greatly with market conditions of grain and live stock, the size of the local harvest, and the ratio of corn to live-stock prices. Trade currents are apt to be irregular in quantity, sometimes in direction also, and farm practice varies with respect to feeding and selling to local or general markets.

The movement to large markets is aided by a highly organized commercial organization and excellent transportation facilities. Moreover, freight rates and competition among large markets tend to stabilize price differences between cities and their tributary territories.

FARM CONSUMPTION.

Economic conditions attending farm consumption make for price irregularity.

Transportation and costs of hauling.

As farm consumption absorbs more than four-fifths of the production, the preponderant influence of farm conditions is evident. Farm conditions are such as to make for price irregularity. The average cost of hauling a few miles from or to shipping points in many regions is greater than the cost of shipping corn to European markets in normal times. An idea of sectional differences in costs of hauling may be gained from the following table showing the average costs as well as the hauling expense from most remote farms.

TABLE 3.—*Average cost of hauling corn from farms to shipping points, 1906.*[1]

State or territory.	Number of counties reported.	Average.					From most remote farms to shipping points.				
		Miles to shipping point.	Days for round trip.	Pounds in one load.	Cost per load.	Cost per 100 pounds.	Miles to shipping point.	Days for round trip.	Pounds in one load.	Cost per load.	Cost per 100 pounds.
North Atlantic:											
New York	3	8.6	0.9	2,917	$3.45	$0.12	25.0	3.0	3,000	$12.00	$0.40
New Jersey	4	3.2	.4	2,475	1.38	.06	5.0	.5	1,400	2.00	.14
Pennsylvania	22	6.6	.6	3,020	2.11	.07	20.0	1.0	2,000	2.50	.12
South Atlantic:											
Maryland	13	5.4	.5	2,985	1.88	.06	12.5	2.0	4,000	10.00	.25
Virginia	32	8.6	1.0	2,416	3.23	.13	22.5	2.0	1,500	5.00	.33
West Virginia	17	10.2	.8	2,124	2.74	.13	25.0	2.0	800	6.00	.75
North Carolina	31	10.6	.8	1,584	1.96	.12	50.0	4.0	1,600	11.00	.69
South Carolina	7	11.7	.9	1,607	2.11	.13	30.0	2.0	1,500	4.00	.27
Georgia	30	11.3	1.1	1,553	2.76	.18	60.0	8.0	1,000	16.00	1.60
Florida	6	7.1	.6	1,533	2.20	.14	17.0	2.0	2,000	8.00	.40
North Central:											
Ohio	51	6.0	.6	3,025	1.93	.06	30.0	2.0	2,000	8.00	.40
Indiana	67	7.4	.6	2,891	1.74	.06	25.0	2.0	2,500	6.00	.24
Illinois	66	5.7	.5	2,754	1.47	.05	24.0	1.5	3,500	6.00	.17
Michigan	17	7.3	.6	2,612	1.78	.07	20.0	1.0	3,000	2.00	.07
Wisconsin	6	7.8	.6	2,583	1.75	.07	16.0	1.0	1,500	3.00	.20
Minnesota	21	7.8	.7	2,807	2.24	.08	20.0	1.0	3,250	3.50	.11
Iowa	69	6.1	.6	2,392	1.79	.07	16.0	2.0	3,500	7.00	.20
Missouri	63	8.8	.8	2,122	2.02	.10	25.0	2.0	1,500	5.00	.33
North Dakota	31	10.6	.8	1,584	1.96	.12	....	....	....	....	....
South Dakota	22	13.3	.9	2,932	3.07	.10	50.0	2.5	2,500	15.00	.60
Nebraska	55	9.1	.7	2,960	2.15	.07	26.5	2.5	4,000	10.00	.25
Kansas	63	7.9	.6	2,908	1.75	.06	25.0	2.0	3,000	7.00	.23
South Central:											
Kentucky	66	9.8	1.0	2,263	2.82	.12	37.5	5.0	1,800	15.00	.83
Tennessee	48	9.5	.8	1,925	1.88	.10	30.0	3.0	1,600	6.00	.38
Alabama	19	12.9	1.2	1,689	3.13	.19	37.5	4.0	1,200	10.00	.83
Mississippi	10	11.6	1.3	1,395	3.06	.22	25.0	3.0	1,200	4.50	.38
Louisiana	5	11.9	1.2	1,850	3.48	.19	32.5	4.0	2,000	12.00	.60
Texas	71	14.0	1.2	2,084	3.35	.16	47.2	4.5	1,100	10.12	.92
Indian Territory	4	7.4	.6	1,730	1.61	.09	15.0	1.0	2,000	2.75	.14
Oklahoma	20	11.9	.9	2,420	2.56	.11	45.0	3.0	2,000	7.50	.38
Arkansas	25	13.0	1.2	1,642	3.26	.20	45.0	4.0	1,600	8.00	.50

Western:											
Colorado	4	24.0	2.1	3,375	6.17	.18	40.0	4.0	2,000	12.00	.60
New Mexico	8	29.4	2.7	2,668	10.12	.38	80.0	5.0	2,000	15.00	.75
Arizona	2	11.5	1.3	3,750	6.82	.18	27.5	2.5	4,500	18.75	.42
California	3	8.5	.9	3,133	3.82	.12	15.0	2.5	1,900	13.75	.72
Geographic division:											
North Atlantic	29	5.9	.6	2,851	2.12	.07	...	...	...	...	...
South Atlantic	136	7.8	.8	2,479	2.66	.11	...	...	...	...	...
North Central	531	7.1	.6	2,758	1.78	.06	...	...	...	...	...
South Central	268	11.0	.9	2,078	2.43	.12	...	...	...	...	...
Western	17	13.7	1.3	3,214	4.95	.15	...	...	...	...	...
States and territories represented	981	7.4	.6	2,696	1.78	.07	...	...	...	...	...

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[1] From "Costs of hauling crops from farms to shipping points," by Frank Andrews. Bul. 49, U. S. Dept. Agri., Bureau of Statistics.

The figures for corn were based upon shelled corn, and costs refer to expense for round trips.

In the surplus-producing North Central States, costs of hauling will be observed to be lower than elsewhere and fairly uniform over large areas. The Southern and Western States are marked by long hauls and high hauling costs, as well as great irregularity in the price areas. Irregular price levels may be observed (Map 3) throughout mountain sections. Accessibility to markets, the existence or absence of good roads or of water transportation, is often reflected in material price variations within small areas. Thus, in a report of the Waterways Commission it is shown that farmers along navigable rivers in Tennessee receive several cents per bushel more for their corn than those in surrounding regions. In the more remote farms the cost of hauling corn to or from shipping points appears to be almost prohibitive. Such isolated areas have an almost entirely local market. In the western irrigated sections—distant from markets—the price of alfalfa hay has been known to drop from around $20 per ton in a year of local shortage to below $5 in a year of local surplus.

To the causes making for price irregularity because of farm conditions may be added the preference for ear corn, the trade for which is local, and the added expense of shelling corn to lessen freight charges.

Local conditions are thus seen to depress farm prices of corn in regions of surplus production, influences of the character mentioned often causing deviations from the general geographic arrangement of prices. But in areas of insufficient production the described drawbacks incident to bringing in corn tend to increase the prices obtained by farmers. Map 2, showing density of production, should be compared with Map 3, which shows prices. The relationship is apparent, for prices drop wherever production is shown to be denser. In the regions of deficient production such areas as show notably heavy corn crops form price depressions. For instance, in Maryland, Delaware, and southeastern Pennsylvania production is greater and corn prices are lower than in surrounding territories; this contrasts with the tendency of corn prices to increase east and southward. In central Tennessee, also, lower prices and greater production will be noted than in the southwestern part of the State.

URBAN MARKETS.

Market receipts, shipments, and consumption.
Urban markets have a stabilizing effect upon price differences.

The corn entering into trade channels has been seen to constitute about 19.4 per cent of the total during 1911–1915. Like other elements in corn distribution, this percentage varies from year to year. Practically all of such shipments move to urban markets, from which in turn approximately 3 per cent is shipped back to farms.

Demands for urban consumption constitute approximately 15 per cent of the total production. Additional quantities, however, are concentrated in the markets for reshipment to domestic and foreign markets. Although urban markets draw only a fifth of the domestic crop, they influence to a considerable degree the general level of farm prices, for the prices obtaining there represent market conditions and the available returns for corn as a cash crop.

Large markets, through their commercial organizations, credit and elevating facilities, tend to stabilize the geographic differences in farm prices. The comparative evenness of the price levels throughout the corn belt, wherein most of the great markets are situated, contrasts with the irregular price levels in areas where no points of large concentration appear. The difference between the prices at any two markets tends to be regulated in the long run by transportation expenses. The prices at markets in areas of insufficient production will generally be fixed by the prices at the nearest surplus point plus transportation expenses. Hence, market prices in cities tend to conform to the general zones for producers' prices, as shown in Maps 1 and 3.

In such farm products as wheat and meat products, which are for human consumption, the relation of production to population dominates the trend of price levels. But large centers of population do not so directly dominate the direction of price increases in such products as corn, which are not destined chiefly for human food but more for consumption by live stock.

Receipts, shipments, and apparent consumption of the largest markets are shown in Table 4. Half a dozen primary markets located in the corn States receive the major part of the commercial corn; i. e., "shipments out of counties where grown." Of these, Chicago is by far the most important. Into the 14 cities listed as primary markets are shipped 264 million out of the 500 million bushels entering into trade channels; the greater part of this comes from the North Central States, in which these markets are located. Although industrial uses, particularly important in such cities as Chicago, Indianapolis, St. Louis, and Peoria (Ill.), absorb large quantities, two-thirds of the total receipts in the primary markets are reshipped. Farm prices are naturally higher in regions near these primary markets than in more remote regions. (See Maps 2 and 3.)

TABLE 4.—*Corn: Commercial movement to and from leading corn markets, and indicated consumption, in five-year averages (1911–1915).*

[From unofficial returns. Allowance should be made for such duplication as intermediate markets crediting themselves with through shipments.]

Market.	Receipts.	Shipments.	Apparent consumption.
Primary markets.	*Bushels.*	*Bushels.*	*Bushels.*
Chicago	110,194,000	78,637,000	31,557,000
Omaha	25,046,000	23,234,000	1,812,000
St. Louis	21,562,000	12,135,000	9,427,000
Kansas City	20,472,000	13,989,000	6,483,000
Peoria	17,672,000	10,179,000	7,493,000
Indianapolis	14,685,000	4,178,000	10,507,000
Milwaukee	12,770,000	9,831,000	2,939,000
Louisville	10,400,000	6,211,000	4,189,000
Minneapolis	8,900,000	6,620,000	2,280,000
Cincinnati	8,651,000	5,281,000	3,370,000
Toledo	4,395,000	2,298,000	2,097,000
Cleveland	4,102,000	1,500,000	2,602,000
Detroit	3,347,000	2,117,000	1,230,000
Duluth	1,464,000	1,193,000	271,000
Total	263,660,000	177,403,000	86,257,000
Denver	2,110,000	(1)	2,110,000
Buffalo	18,737,000	(1)	(1)
		Exports.	
Baltimore	14,845,000	11,981,000	2,864,000
New York	12,660,000	7,323,000	5,337,000
New Orleans	5,158,000	3,835,000	1,323,000
Philadelphia	3,896,000	1,947,000	1,949,000
Boston	2,803,000	2,616,000	187,000
Newport News	(1)	1,844,000	(1)
Galveston	(1)	338,000	(1)
Pacific markets.			
San Francisco	342,000	137,000	205,000
Seattle	744,000	30,000	714,000

[1] No data available.

To the above figures should be added relatively insignificant quantities of corn meal. Largest receipts of corn meal appear at New York, 662,000 barrels, and Baltimore, 405,000 barrels. A few other markets show small receipts, none averaging over 50,000 barrels.

FREIGHT RATES.

Freight rates constitute an important factor affecting differences in price between two regions. Corn frequently takes a lower rate than wheat, for not only is the weight per bushel slightly less but frequently a lower freight rate per 100 pounds applies. A detailed statement of freight rates is beyond the purpose of this publication, but a few of the more important phases may be noted briefly in their relation to differences in farm prices of corn.

Distance is an important element in freight rates, but they are not directly proportionate thereto. The following illustration will serve:

Distance rates between points in Iowa and Missouri, C. B. & Q. Ry.

[Freight rates per bushel of corn (carlot shipments) in 1916.]

Number of miles.	Rate per bushel.
10	$0.031
100	.071
200	.088
300	.102
400	.115

Thus forty times the distance takes less than four times the ten-mile rate. The through rates from a point in the corn belt apply to all New England destinations; the rate to Baltimore applies equally to Richmond and Newport News.

Moreover, the sum of a series of local rates covering a given route is usually higher than the through rate over the same route. Also, export grain usually moves to the seaboard at lower rates than does grain for domestic use. A higher rate applies to grain products than to grain. Lower rates usually prevail at points possessing water transportation, which serves as a potential if not an actual competitive factor.

The influence of markets upon farm prices, as well as the tendency to concentrate the commercial corn in the large commercial centers, is affected by freight rates.

By means of the milling-in-transit rate, corn may be stopped en route, milled, cleaned, or dried, and the product moved on again at the original rate charged for a through corn shipment, instead of taking the local rate to the milling point and the higher rate for grain products to eventual destination. On some lines the rate for grain products is applied to such traffic.

It may be noted that the tendency to manufacture cereal products near sources of supply and lessen transportation costs is somewhat offset by this higher rate for grain products as well as by reshipping and milling-in-transit rates.

Rates on corn from the North Central States to the Southeast are considerably higher than to New England or eastern points; before the war they were higher even than transportation costs from points in the corn belt to British markets. This fact is suggestive when considered in connection with the higher prices paid to corn growers in the Southeast, where production is less than consumption.

The difference in freight rates between carload and less-than-carload lots represents still another factor in the price zones, affecting especially sections in which corn traffic is small. In the territory east of the Mississippi and south of the Potomac and Ohio Rivers the same rate applies to carload and less-than-carload lots of corn.

COSTS OF PRODUCTION AND FARM PRICES, GEOGRAPHIC DIFFERENCES.

An analysis of the practical bearing of varying price levels on local types of agriculture is incomplete without consideration of cost to production. Two elements are involved here: (1) The cost of producing crops upon an acreage basis, and (2) the number of bushels produced to the acre.

Figure 4 throws into relief the relationship of these factors. It will be observed that often areas of high price show minimum net returns, higher prices being offset either by high costs of production or low yields in bushels to the acre. Varying land rental or interest charges, also costs of commercial fertilizer, enter into the cost factor.

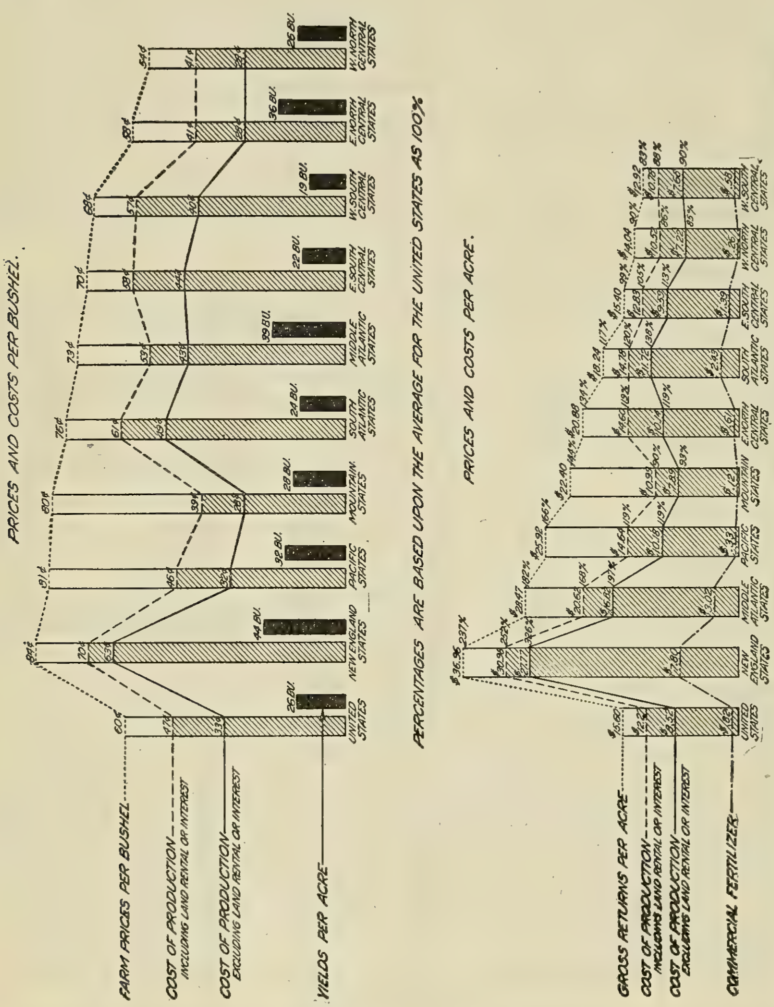

FIG. 4.—Corn: Farm prices, yields, and costs of production, by geographic divisions. For details see table.

In the upper illustration on figure 4 prices and costs per bushel are given, and in the lower the data are upon an acreage basis.

The New England States stand out prominently with highest prices per bushel and highest production per acre. But these are offset by maximum costs of production (in which high values of commercial fertilizer enter), with a resulting low ratio of money returns.

The favorable combination of high price per bushel and lowest cost per acre obtains in the Southern States, but average yields are so low as to make the cost per bushel very high, with resulting minimum net returns. Highest net returns are indicated for the Mountain and Pacific States. Here, however, a relatively lower percentage of merchantable corn must be taken into consideration.

Details follow in Tables 5 and 5A. Relationships can best be observed in the percentages, based upon the United States as 100 per cent. By way of example: Iowa farm price per bushel, only 85 per cent of the average for the United States, but yield per acre 135 per cent; and combining the two in gross returns to the acre, 114 per cent. Costs of production in Iowa, however, are slightly above the average, being 101 per cent, and the ratio of returns to cost is 145 per cent.

TABLE 5.—*Corn: Geographic differences in values and costs of production.*[1]

PER ACRE.

State and geographic divisions.	Average gross returns, 1911–1915 (price per bushel × yield).[1]	Cost of production, 1909.			Ratio of cost to gross returns[2] (cost = 100 per cent).	Value of by-products, 1909.	Comparison of preceding differences in percentages of the United States average as base (100 per cent).		
		Cost, including land rental or interest.	Cost, excluding land rental or interest.	Commercial fertilizer in total cost.			Gross returns.	Cost, including land rental or interest.	Cost, excluding land rental or interest.
	Per acre	*Per acre*	*Per acre*	*Per acre*	*Per cent*	*Per acre*	*Per cent*	*Per cent*	*Per cent*
United States	**$15.60**	**$12.27**	**$8.52**	**$0.82**	**127**	**$1.20**	**100**	**100**	**100**
New England	36.96	30.98	27.77	7.80	120	7.78	237	252	326
Middle Atlantic	28.47	20.62	16.82	3.02	138	5.04	182	168	197
South Atlantic	18.24	14.78	11.72	2.43	124	2.34	117	120	138
East North Central	20.88	14.60	10.14	.61	143	2.23	134	119	119
West North Central	14.04	10.52	7.22	.26	133	.94	90	86	85
East South Central	15.40	12.83	9.59	1.39	120	1.16	99	105	113
West South Central	12.92	10.78	7.68	.58	120	.90	83	88	90
Mountain	22.40	10.99	7.89	.12	204	1.80	144	90	93
Pacific	25.92	14.64	10.18	.33	177	3.11	166	119	119
New England:									
Maine	35.70	37.05	34.55	10.67	96	5.50	229	302	406
New Hampshire	34.76	30.73	27.54	5.92	113	7.83	223	250	323
Vermont	33.60	27.68	24.20	4.48	121	9.02	215	226	284
Massachusetts	36.90	29.04	25.54	8.00	127	9.00	237	237	300
Rhode Island	40.32	28.12	25.37	8.00	143	9.00	258	229	298
Connecticut	39.48	33.26	29.43	9.70	119	6.33	253	271	345
Middle Atlantic:									
New York	28.86	21.84	18.15	2.80	132	5.91	185	178	213
New Jersey	27.74	22.08	17.91	4.26	126	4.96	178	180	210
Pennsylvania	28.29	17.93	14.41	2.00	157	4.25	181	146	169

[1] Costs of production from a special inquiry of the Bureau of Crop Estimates ("Crop Reporter," April, 1911). Although the data were compiled in the year 1909, they were collated on a uniform and comparable basis, and for the present purpose of comparing average cost conditions in one State or section with another they possess particular value.

[2] Excluding by-products, which were considered as being offset, roughly, by values of farm manure applied.

TABLE 5.—*Corn: Geographic differences in values and costs of production*—Con.

PER ACRE—Continued.

State and geographic divisions.	Average gross returns, 1911–1915 (price per bushel × yield).	Cost of production, 1909.			Ratio of cost to gross returns (cost = 100 per cent).	Value of by-products, 1909.	Comparison of preceding differences in percentages of the United States average as base (100 per cent).		
		Cost, including land rental or interest.	Cost, excluding land rental or interest.	Commercial fertilizer in total cost.			Gross returns.	Cost, including land rental or interest.	Cost, excluding land rental or interest.
South Atlantic:	*Per acre*	*Per acre*	*Per acre*	*Per acre*	*Per cent*	*Per acre*	*Per cent*	*Per cent*	*Per cent*
Delaware	$19.47	$16.54	$13.04	$2.75	118	$4.00	125	135	153
Maryland	22.32	15.36	12.23	2.03	145	3.34	143	125	144
Virginia	18.50	13.90	10.87	1.86	133	2.20	118	113	128
West Virginia	23.56	16.21	12.98	1.14	146	2.04	151	132	152
North Carolina	15.77	15.13	11.66	2.40	104	1.98	101	123	137
South Carolina	16.20	15.83	12.56	4.48	102	2.74	104	129	147
Georgia	12.60	13.26	10.18	2.44	95	1.90	81	108	119
Florida	11.85	12.01	10.21	2.34	98	.53	76	98	120
East North Central:									
Ohio	22.80	15.41	11.09	.99	148	2.39	146	126	130
Indiana	19.61	13.80	8.78	.74	142	1.09	126	112	103
Illinois	18.15	13.25	7.59	.31	137	.67	116	108	89
Michigan	22.10	16.05	12.52	.66	138	3.85	142	131	147
Wisconsin	21.35	14.48	10.73	.36	147	3.14	137	118	126
West North Central:									
Minnesota	16.83	12.04	9.23	.60	140	1.52	108	98	108
Iowa	17.85	12.39	7.76	.21	145	.80	114	101	91
Missouri	15.25	10.45	6.81	.24	146	.62	98	85	80
North Dakota	13.44	9.71	7.63	.27	138	2.02	86	79	90
South Dakota	13.23	9.91	7.05	.31	133	.68	85	81	83
Nebraska	11.73	10.01	6.33	.16	117	.41	75	82	74
Kansas	10.62	9.16	5.74	.04	116	.55	68	75	67
East South Central:									
Kentucky	16.38	12.81	8.83	.77	128	.91	105	104	104
Tennessee	16.25	12.41	8.86	.63	130	.80	104	101	104
Alabama	13.43	13.59	11.04	2.65	99	1.44	86	111	130
Mississippi	13.68	12.52	9.62	1.50	109	1.50	88	102	113
West South Central:									
Louisiana	14.20	12.24	9.28	1.29	116	1.53	91	100	109
Texas	14.40	10.29	7.05	.40	140	.55	92	84	83
Oklahoma	9.44	8.59	5.80	.01	110	.26	61	70	68
Arkansas	14.40	12.01	8.59	.61	120	1.27	92	98	101
Mountain:									
Montana	20.72	....	....	....	....	....	133	....	....
Wyoming	16.33	9.95	7.08	.06	164	2.00	105	81	83
Colorado	11.97	8.97	6.39	.07	133	1.06	77	73	75
New Mexico	18.48	11.30	8.24	.00	164	2.04	118	92	97
Arizona	33.48	....	....	....	....	....	215	....	....
Utah	25.84	....	....	....	....	....	166	....	....
Nevada	33.66	....	....	....	....	....	216	....	....
Idaho	23.04	13.73	9.86	.33	168	2.10	148	112	116
Pacific:									
Washington	21.56	11.92	8.57	.72	180	4.55	138	97	101
Oregon	24.18	13.19	9.09	.28	182	3.50	155	107	107
California	32.56	18.82	12.87	.00	173	1.28	209	153	151
United States	15.60	12.27	8.52	.82	127	1.20	100	100	100

TABLE 5A.—*Corn: Geographic differences in farm prices and costs of production.*

PER BUSHEL.

State and geographic divisions.	Bushels produced per acre (average, 1911–1915).	Farm price (average 1911–1915).	Cost of production.[1]		Ratio of cost to price (cost = 100 per cent).	Comparisons in percentages of the United States average as base (100 per cent).			
			Including land rental or interest.	Excluding land rental or interest.		Bushels per acre.	Farm price.	Cost of production.	
								Including land rental or interest.	Excluding land rental or interest.
	Bushels.	*Cents per bushel.*	*Cents per bushel.*	*Cents per bushel.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
United States	**26**	**60**	**47**	**33**	**127**	**100**	**100**	**100**	**100**
New England	44	84	70	63	120	169	140	148	192
Middle Atlantic	39	73	53	43	138	150	122	112	131
South Atlantic	24	76	61	49	124	92	127	129	150
East North Central	36	58	41	28	143	138	97	87	85
West North Central	26	54	41	28	133	100	90	87	85
East South Central	22	70	58	44	120	85	117	123	134
West South Central	19	68	57	40	120	73	113	119	122
Mountain	28	80	39	28	204	108	133	83	85
Pacific	32	81	46	32	177	123	135	97	98
New England:									
Maine	42	85	88	82	96	162	142	186	250
New Hampshire	44	79	70	63	113	169	132	148	192
Vermont	42	80	66	58	121	162	133	140	177
Massachusetts	45	82	65	57	127	173	137	138	174
Rhode Island	42	96	67	60	143	162	160	142	183
Connecticut	47	84	71	63	119	181	140	150	192
Middle Atlantic:									
New York	37	78	59	49	132	142	130	125	150
New Jersey	38	73	58	47	126	146	122	123	143
Pennsylvania	41	69	44	35	157	158	115	93	107
South Atlantic:									
Delaware	33	59	50	40	118	127	98	106	122
Maryland	36	62	43	34	145	138	103	91	104
Virginia	25	74	56	43	133	96	123	119	131
West Virginia	31	76	52	42	146	119	127	110	128
North Carolina	19	83	80	61	104	73	138	170	186
South Carolina	18	90	88	70	102	69	150	186	214
Georgia	15	84	88	68	95	58	140	186	208
Florida	15	79	80	68	98	58	132	170	208
East North Central:									
Ohio	40	57	39	28	148	154	95	83	85
Indiana	37	53	37	24	142	142	88	78	73
Illinois	33	55	40	23	137	127	92	85	70
Michigan	34	65	47	37	138	131	108	100	113
Wisconsin	35	61	41	31	147	135	102	87	95
West North Central:									
Minnesota	33	51	36	28	140	127	85	76	85
Iowa	35	51	35	22	145	135	85	74	67
Missouri	25	61	42	27	146	96	102	89	82
North Dakota	24	56	40	32	138	92	93	85	98
South Dakota	27	49	37	26	133	104	82	78	79
Nebraska	23	51	44	28	117	88	85	93	85
Kansas	18	59	51	32	116	69	98	108	98
East South Central:									
Kentucky	26	63	49	34	128	100	105	104	104
Tennessee	25	65	50	35	130	96	108	106	107
Alabama	17	79	80	65	99	65	132	170	198
Mississippi	19	72	66	51	109	73	120	140	156
West South Central:									
Louisiana	20	71	61	46	116	77	118	129	140
Texas	20	72	51	35	140	77	120	108	107
Oklahoma	16	59	54	36	110	62	98	114	110
Arkansas	20	72	60	43	120	77	120	127	131

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[1] Costs per bushel obtained by dividing costs per acre (see Table 5) by average yield per acre, 1911–1915. Figures for cost per acre are comparatively stable.

TABLE 5A.—*Corn: Geographic differences in farm prices and costs of production*—Continued.

PER BUSHEL—Continued.

State and geographic divisions.	Bushels produced per acre (average, 1911–1915).	Farm price (average, 1911–1915).	Cost of production.		Ratio of cost to price (cost = 100 per cent).	Comparisons in percentages of the United States average as base (100 per cent).			
			Including land rental or interest.	Excluding land rental or interest.		Bushels per acre.	Farm price.	Cost of production.	
								Including land rental or interest.	Excluding land rental or interest.
	Bushels.	*Cents per bushel.*	*Cents per bushel.*	*Cents per bushel.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Mountain:									
Montana	28	74	....	....	....	108	123	....	....
Wyoming	23	71	43	31	164	88	119	91	95
Colorado	19	63	47	34	133	73	105	100	104
New Mexico	24	77	47	34	164	92	128	100	104
Arizona	31	108	....	....	....	119	180	....	....
Utah	34	76	....	....	....	131	127	....	....
Nevada	33	102	....	....	....	127	170	....	....
Idaho	32	72	43	31	168	123	120	91	95
Pacific:									
Washington	28	77	43	31	180	108	128	91	95
Oregon	31	78	43	29	182	119	130	91	88
California	37	88	51	35	173	142	147	108	107
United States	26	60	47	33	127	100	100	100	100

CHARACTERISTICS OF PRICE ZONES.

A brief explanation of the characteristics of the apparent differences seems necessary to avoid error in the practical application of the detailed figures of the farm prices of corn by States and counties.

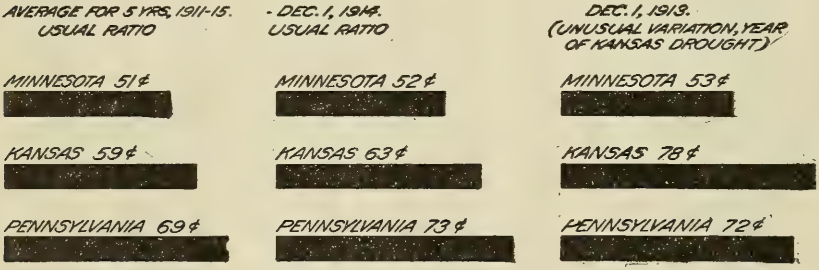

FIG. 5.—Showing usual geographic difference in farm prices of corn, and variation therefrom.

To determine normal conditions the data forming the base of the maps were arranged and zones determined according to the five-year averages (1910–1914). Prices in a single year, of course, may be greater or less than the average. Unusual harvest or market circumstances which alter the ordinary course of the corn trade may alter price ratios between two localities. The quality of the local corn crop may be poor, or a local failure may occur and a territory usually producing a surplus may have to ship in corn.

As an instance in point: Kansas, usually a corn-exporting State, had to import large quantities of corn on account of the State's crop failure in 1913. The relatively high freight rates on corn into Kansas added to the disadvantage caused by the crop failure. Kansas corn prices, usually only a few cents higher than those of Minnesota, in that year averaged 25 cents per bushel higher; they were even higher than those of Pennsylvania—far to the east and usually on a considerably higher level.

RETROSPECTIVE VIEW OF PRICES AND PRICE FACTORS, 1871–1915.

TREND OF FARM PRICES.

A review of the trend of geographic differences in farm prices of corn for a series of years reflects sharply economic transformations within the United States, and particularly reduced costs of transportation and marketing. It also indicates present tendencies. Table 8 shows the trend of farm prices of corn and the sectional variations therein from 1871 to 1915. An average of five years was

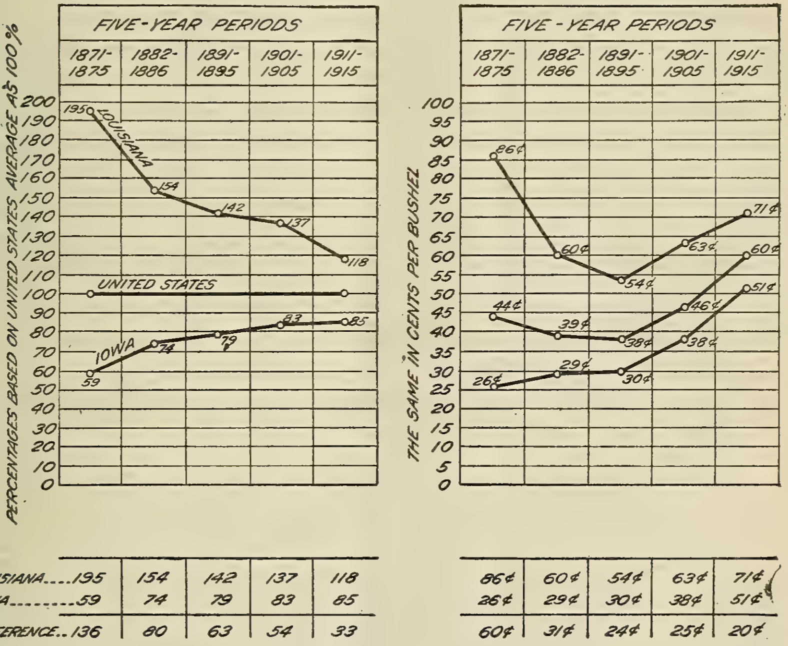

FIG. 6.—Illustrating trend of geographic differences in farm prices of corn, 1871–1915. Iowa: Example of corn-surplus State; Louisiana: Example of corn-deficiency State.

employed to show predominant conditions at each period. Units of measurement are averages for States and geographic divisions.

Extreme price differences are indicated at the opening period, when farmers in some corn-deficiency States received fully four times as much for their corn as in certain surplus-producing States. Such price differences have narrowed notably, and only by including insignificant quantities raised in Nevada and Arizona can even 100 per cent variation be found between two States. The geographic differences have been cut in two.

The minimum price has moved north and west; in 1871–1875 it appeared in Iowa, in 1882–1886 in Nebraska, and in 1911–1915 in South Dakota.

The general level of corn prices, that is, the average farm price for the United States, at first declined, reaching its lowest in 1891–1895, then rose to higher levels. But in the corn belt prices rose steadily throughout the whole period; in some cases they were doubled. In the corn-deficiency States a contrary tendency is evidenced; farm prices have fallen away in the States most highly deficient, as in New England and the far South; in others they have remained stationary, or have increased, as in the Middle Atlantic section and the northern tier of the Southern States, but in far less ratio than in the exporting or corn-surplus States.

The trend of geographic prices may be more clearly seen in the percentages; these are based upon the United States average as 100 for each period, to reduce the figures to a comparable standard. The price percentage in corn-deficiency States (the percentage of the United States average) has declined rapidly, but in the corn-exporting States it has risen steadily. Prices of corn in Iowa and Louisiana have been plotted on figure 6. The difference in favor of the Louisiana grower at the beginning was 60 cents per bushel; at the latter period 20 cents. The Louisiana price declined from 86 cents to 71 cents, and the State's percentage of the United States average from 195 to 118, while the Iowa price rose from 26 cents to 51 cents, and the price percentage from 59 to 85.

TABLE 6.—*Corn: Review of farm prices, 1871–1915, by States and sections, showing geographic trend in the price differences.*

State and geographic division.	Farm prices, per bushel, in five-year averages.					Measurement of tendencies in percentages of the United States average as base.				
	1911–1915	1901–1905	1891–1895	1882–1886[1]	1871–1875[2]	1911–1915	1901–1905	1891–1895	1882–1886	1871–1875
United States	*Cts.* **60**	*Cts.* **46**	*Cts.* **38**	*Cts.* **39**	*Cts.* **44**	*Per ct.* **100**	*Per ct.* **100**	*Per ct.* **100**	*Per ct.* **100**	*Per ct.* **100**
New England	84	72	65	77	87	140	157	171	197	198
Middle Atlantic	73	60	54	61	64	122	131	142	156	145
South Atlantic	76	63	52	58	67	127	137	137	149	152
East North Central	58	45	38	40	40	97	98	100	103	91
West North Central	54	39	33	31	33	90	85	87	79	75
East South Central	70	57	45	51	85	117	124	118	130	193
West South Central	68	56	48	56	74	113	122	126	143	168
Mountain	80	71	65	79	......	133	154	171	203	......
Pacific	81	66	57	74	94	135	144	150	190	213
New England:										
Maine	85	73	67	77	88	142	159	176	197	200
New Hampshire	79	71	65	79	87	132	154	171	203	198
Vermont	80	69	64	74	84	133	150	168	190	191
Massachusetts	82	72	63	77	85	137	156	166	197	193
Rhode Island	96	78	68	79	88	160	170	179	203	200
Connecticut	84	72	64	74	91	140	157	168	190	207
Middle Atlantic:										
New York	78	65	57	65	70	130	141	150	167	159
New Jersey	73	58	54	60	62	122	126	142	154	141
Pennsylvania	69	58	51	57	59	115	126	134	146	134
South Atlantic:										
Delaware	59	50	44	47	53	98	109	116	120	120
Maryland	62	52	46	49	57	103	113	121	126	130
Virginia	74	55	47	52	54	123	120	124	133	123
West Virginia	76	60	52	50	52	127	130	137	128	118
North Carolina	83	64	49	58	59	138	139	129	149	134
South Carolina	90	73	60	65	86	150	159	158	167	195
Georgia	84	73	56	64	79	140	159	147	164	180
Florida	79	75	65	77	98	132	163	171	197	223
East North Central:										
Ohio	57	47	39	43	40	95	102	103	110	91
Indiana	53	41	35	37	35	88	89	92	95	80
Illinois	55	41	33	35	32	92	89	87	90	73
Michigan	65	50	44	45	49	108	109	116	115	111
Wisconsin	61	47	38	41	44	102	102	100	105	100
West North Central:										
Minnesota	51	38	35	37	39	85	83	92	95	89
Iowa	51	38	30	29	26	85	83	79	74	59
Missouri	61	43	33	31	36	102	93	87	80	82
North Dakota	56	42	37	38	......	93	91	97	97	......
South Dakota	49	38	32		......	82	83	84		......
Nebraska	51	35	30	23	29	85	76	79	59	66
Kansas	59	41	32	27	35	98	89	84	69	80
East South Central:										
Kentucky	63	50	39	41	40	105	109	103	105	91
Tennessee	65	52	38	42	48	108	113	100	108	109
Alabama	79	65	53	60	76	132	141	139	154	173
Mississippi	72	62	50	59	80	120	135	132	151	182
West South Central:										
Louisiana	71	63	54	60	86	118	137	142	154	195
Texas	72	59	48	57	70	120	128	126	146	159
Oklahoma	59	45	......	......	......	98	98	......	......	......
Arkansas	72	58	43	50	66	120	126	113	128	150
Mountain:										
Montana	74	72	74	93	......	123	157	195	238	......
Wyoming	71	64	62	......	......	119	139	163	......	......
Colorado	63	58	49	72	......	105	126	129	185	......
New Mexico	77	75	69	82	......	128	163	182	210	......
Arizona	108	94	76	......	......	180	204	200	......	......
Utah	76	74	57	74	......	127	161	150	190	......
Nevada	102	......	......	70	......	170	......	......	179	......
Idaho	72	63	65	84	......	120	137	171	215	......
Pacific:										
Washington	77	61	58	78	......	128	133	153	200	......
Oregon	78	62	57	72	88	130	135	150	185	200
California	88	75	57	72	99	147	163	150	185	225

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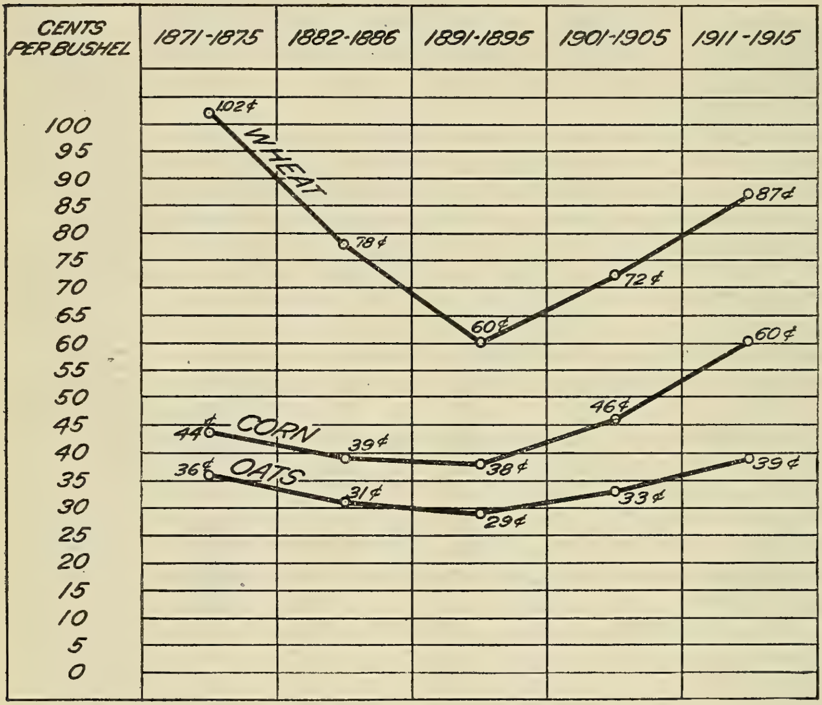
[1] Five-year average 1882–1886 used, because of availability of statistics for a larger number of States beginning 1882.
[2] Values reduced to gold basis.

Prices are based upon shelled corn, at 56 pounds per bushel.

THE DISPARITY IN PRICES OF CORN, WHEAT, AND OATS DECREASING.

As the price of one cereal affects that of the others to a considerable degree, their relationship is suggestive. The difference between corn and wheat prices has been steadily diminishing. At the beginning (1871–1875) the average farm price of wheat in the United States on December 1 was 58 cents more than that of corn (wheat $1.02, corn 44 cents); at the end only 27 cents (wheat 87 cents, corn 60 cents), the average wheat price dropping from two and one-third times that of corn to only about one and one-half times. But as the price of oats has not increased as rapidly, the disparity between corn and oats has increased, between wheat and oats has narrowed; wheat has dropped from about three times the price of oats to a little over twice its level.



DIFFERENCES PER BUSHEL.

	1871-1875	1911-1915
CORN	58¢ BELOW WHEAT 8¢ OVER OATS	27¢ BELOW WHEAT 21¢ OVER OATS
OATS	66¢ BELOW WHEAT 8¢ BELOW CORN	48¢ BELOW WHEAT 21¢ BELOW CORN

FIG. 7.—Course of farm prices of wheat, corn, and oats, showing lessening differences.

Another element which should be taken into consideration is the larger yield in bushels to the acre of corn and oats compared with wheat.

Figure 7 refers to the general level (the average for the United States). When the trend of farm prices of corn, wheat, and oats is compared for each State or section, it appears that in some the tendency pointed out is more marked, in others less so, and in still others a contrary trend appears. In Virginia the difference between wheat and corn prices dropped from 68 cents (1871–1875) to 28 cents (1911–1915). On the other hand, in South Dakota wheat was but 18 cents higher than corn in 1891–1895, and in 1911–1915 the difference increased to 33 cents per bushel.

TREND OF YIELDS TO THE ACRE.

The trend of yields, which must be taken into consideration as qualifying price conditions, is given in Table 7 in absolute and relative figures. Changes can best be followed in the percentages.

The average yield for the United States (number of bushels produced to the acre) has remained about stationary during the half century under review. While increasing yields are shown in by far the greater number of States, a decided decline is in evidence in most of the great corn States. As the latter produce the greater part of the national crop, they have a strong depressing effect on the weighted general average.

Most pronounced advances in yields to the acre are shown in the two divisions comprising the North Atlantic States. While yields lower than in other sections still prevail in the Southern States, more especially in those farthest south, it is in the latter that the increases are most notable.

The important exception to the general tendency toward larger yields appears in the newer States, particularly in the great corn States west of the Mississippi. Here a more or less decided decline is in evidence. Details follow.

TABLE 7.—*Corn: Trend of yields per acre, 1871 to 1915, and geographic comparisons.*

[Natural limitations, reflected in yields per acre, as qualifying price factors.]

States and geographic divisions.	Yields to the acre, in 5-year averages.					Measurement of changes in percentages of the United States average as base (100 per cent).				
	1911–1915.	1901–1905.	1891–1895.	1882–1886.	1871–1875.	1911–1915.	1901–1905.	1891–1895.	1882–1886.	1871–1875.
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
United States	**26**	**25**	**24**	**24**	**27**	**100**	**100**	**100**	**100**	**100**
New England	44	32	36	32	32	168	129	149	131	119
Middle Atlantic	39	32	32	30	36	149	129	132	124	133
South Atlantic	24	19	16	15	18	92	78	69	63	65
East North Central	36	32	29	29	32	138	129	119	120	120
West North Central	26	26	24	30	33	102	105	99	124	122
East South Central	22	19	19	18	20	84	75	79	75	75
West South Central	19	18	19	18	20	73	74	78	75	73
Mountain	28	25	22	23	......	108	98	93	98	......
Pacific	32	26	25	26	32	123	103	104	108	120
New England:										
Maine	42	33	37	33	28	162	132	154	138	104
New Hampshire	44	29	36	32	37	169	116	150	133	137
Vermont	42	31	39	33	36	162	124	162	138	133
Massachusetts	45	34	38	31	34	173	136	158	129	126
Rhode Island	42	31	31	30	28	162	124	129	125	104
Connecticut	47	35	34	30	30	181	140	142	125	111
Middle Atlantic:										
New York	37	28	32	29	33	142	112	133	121	122
New Jersey	38	34	32	30	38	146	136	133	125	141
Pennsylvania	41	35	31	30	37	158	140	129	125	137
South Atlantic:										
Delaware	33	29	22	18	21	127	116	92	75	78
Maryland	36	33	24	23	24	138	132	100	96	89
Virginia	25	23	18	16	21	96	92	75	67	78
West Virginia	31	25	23	23	28	119	100	96	96	104
North Carolina	19	14	13	12	15	73	56	54	50	56
South Carolina	18	10	10	9	10	69	40	42	38	37
Georgia	15	11	12	11	11	58	44	50	46	41
Florida	15	10	10	9	10	58	40	42	38	37
East North Central:										
Ohio	40	33	29	31	37	154	132	121	129	137
Indiana	37	33	30	31	32	142	132	125	129	119
Illinois	33	34	30	27	30	127	136	125	112	111
Michigan	34	31	27	29	32	131	124	112	121	119
Wisconsin	35	30	27	26	31	135	120	112	108	115
West North Central:										
Minnesota	33	27	26	29	33	127	108	108	121	122
Iowa	35	30	30	28	35	135	120	125	117	130
Missouri	25	28	29	29	30	96	112	121	121	111
North Dakota	24	23	20	25	......	92	92	83	104	......
South Dakota	27	25	17			104	100	71		
Nebraska	23	28	22	35	33	88	112	92	146	122
Kansas	18	22	22	32	34	69	88	92	133	126
East South Central:										
Kentucky	26	25	26	24	29	100	100	108	100	107
Tennessee	25	22	22	21	22	96	88	92	88	81
Alabama	17	13	13	13	14	65	52	54	54	52
Mississippi	19	15	15	14	16	73	60	62	58	59
West South Central:										
Louisiana	20	16	16	16	16	77	64	67	67	59
Texas	20	18	21	18	20	77	72	88	75	74
Oklahoma	16	22	......	......	......	62	88	......	......	......
Arkansas	20	18	19	20	23	77	72	79	83	85
Mountain:										
Montana	28	23	26	26	......	108	92	108	108	......
Wyoming	23	28	24	......	......	88	112	100	......	......
Colorado	19	20	20	28	......	73	80	83	117	......
Mew Mexico	24	25	22	20	......	92	100	92	83	......
Arizona	31	22	20	21	......	119	88	83	88	......
Utah	34	26	21	23	......	131	104	88	96	......
Nevada	33	......	......	24	......	127	......	......	100	......
Idaho	32	28	24	22	......	123	112	100	92	......
Pacific:										
Washington	28	22	19	26	......	108	88	79	108	......
Oregon	31	24	25	25	28	119	96	104	104	104
California	37	31	31	27	37	142	124	129	112	137

TREND OF GROSS RETURNS TO THE ACRE.

The correlation between geographic differences in price per bushel and the number of bushels grown to the acre has been developed in table 8.

It has been seen that cheapening transportation and marketing costs have reduced greatly the price advantage of corn growers in States of insufficient production, but that a corresponding increase has taken place in the surplus-producing States. It was pointed out, on the other hand, that in the latter, yields to the acre have generally remained stationary or declined, although a marked improvement in yields is shown in the deficiency States.

In combining these two elements it appears that the general average of gross money values to the acre (price × yield) has increased, and so also have the figures for each State—some slightly, others greatly; but that, in relation to the mounting United States average, either steadily dwindling or rising ratios are shown.

Comparing the progress of the States producing insufficient corn for their needs with the advances in the United States average, the South Atlantic division alone shows an increasing ratio of returns to the acre; the North Atlantic and East South Central divisions are about stationary compared to the general level, and the Mountain and Pacific sections show a notable and steady decline in such a comparison.

With respect to the two surplus-producing divisions, the East North Central States show a marked improvement in relative advantage as seen in the percentage column, but the West North Central States (with the single exception of Iowa) show declines more or less pronounced. Kansas, for instance, dropped from 100 per cent to 68 per cent of the United States average.

TABLE 8.—*Corn: Gross returns per acre (yield per acre × price per bushel).*

[A review, by States, of the trend of returns per acre of corn, 1871 to 1915.]

States and geographic divisions.	Gross returns per acre.					Measurement of changes in percentages of the average for the United States as base (100).				
	1911–1915.	1901–1905.	1891–1895.	1882–1886.	1871–1875.	1911–1915.	1901–1905.	1891–1895.	1882–1886.	1871–1875.
	Dolls.	*Dolls.*	*Dolls.*	*Dolls.*	*Dolls.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
United States	**15.60**	**11.50**	**9.12**	**9.36**	**11.88**	**100**	**100**	**100**	**100**	**100**
New England	36.96	23.04	23.40	24.64	27.84	237	200	257	263	234
Middle Atlantic	28.47	19.20	17.28	18.30	23.04	182	167	189	196	194
South Atlantic	18.24	11.97	8.32	8.70	12.06	117	104	91	93	102
East North Central	20.88	14.40	11.02	11.60	12.80	134	125	121	124	108
West North Central	14.04	10.14	7.92	9.30	10.89	90	88	87	99	92
East South Central	15.40	10.83	8.55	9.18	17.00	99	94	94	98	143
West South Central	12.92	10.08	9.12	10.08	14.80	83	88	100	108	125
Mountain	22.40	17.75	14.30	18.17	....	144	154	157	194	......
Pacific	25.92	17.16	14.25	19.24	30.08	166	149	156	206	253
New England:										
Maine	35.70	24.09	24.79	25.41	24.64	229	209	272	271	207
New Hampshire	34.76	20.59	23.40	25.28	32.19	223	179	257	270	271
Vermont	33.60	21.39	24.96	24.42	30.24	215	186	274	261	255
Massachusetts	36.90	24.48	23.94	23.87	28.90	237	213	263	255	243
Rhode Island	40.32	24.18	21.08	23.70	24.64	258	210	231	253	207
Connecticut	39.48	25.20	21.76	22.20	27.30	253	219	239	237	230
Middle Atlantic:										
New York	28.86	18.20	18.24	18.85	23.10	185	158	200	201	194
New Jersey	27.74	19.72	17.28	18.00	23.56	178	171	189	192	198
Pennsylvania	28.29	20.30	15.81	17.10	21.83	181	177	173	183	184
South Atlantic:										
Delaware	19.47	14.50	9.68	8.46	11.13	125	126	106	90	94
Maryland	22.32	17.16	11.04	11.27	13.68	143	149	121	120	115
Virginia	18.50	12.65	8.46	8.32	11.34	118	110	93	89	95
West Virginia	23.56	15.00	11.96	11.50	14.56	151	130	131	123	123
North Carolina	15.77	8.96	6.37	6.96	8.85	101	78	70	74	74
South Carolina	16.20	7.30	6.00	5.85	8.60	104	63	66	62	72
Georgia	12.60	8.03	6.72	7.04	8.69	81	70	74	75	73
Florida	11.85	7.50	6.50	6.93	9.80	76	65	71	74	82
East North Central:										
Ohio	22.80	15.51	11.31	13.33	14.80	146	135	124	142	125
Indiana	19.61	13.53	10.50	11.47	11.20	126	118	115	123	94
Illinois	18.15	13.94	9.90	9.45	9.60	116	121	109	101	81
Michigan	22.10	15.50	11.88	13.05	15.68	142	135	130	139	132
Wisconsin	21.35	14.10	10.26	10.66	13.64	137	123	113	114	115
West North Central:										
Minnesota	16.83	10.26	9.10	10.73	12.87	108	89	100	115	108
Iowa	17.85	11.40	9.00	8.12	9.10	114	99	99	87	77
Missouri	15.25	12.04	9.57	8.99	10.80	98	105	105	96	91
North Dakota	13.44	9.66	7.40	9.50	....	86	84	81	101	......
South Dakota	13.23	9.50	5.44			85	83	60		
Nebraska	11.73	9.80	6.60	8.05	9.57	75	85	72	86	81
Kansas	10.62	9.02	7.04	8.64	11.90	68	78	77	92	100
East South Central:										
Kentucky	16.38	12.50	10.14	9.84	11.60	105	109	111	105	98
Tennessee	16.25	11.44	8.36	8.82	10.56	104	99	92	94	89
Alabama	13.43	8.45	6.89	7.80	10.64	86	73	76	83	90
Mississippi	13.68	9.30	7.50	8.26	12.80	88	81	82	88	108
West South Central:										
Louisiana	14.20	10.08	8.64	9.60	13.76	91	88	95	103	116
Texas	14.40	10.62	10.08	10.26	14.00	92	92	111	110	118
Oklahoma	9.44	9.90	....	....	....	61	86	......	......	......
Arkansas	14.40	10.44	8.17	10.00	15.18	92	91	90	107	128
Mountain:										
Montana	20.72	16.56	19.24	24.18	....	133	144	211	258	......
Wyoming	16.33	17.92	14.88	....	....	105	156	163	......	......
Colorado	11.97	11.60	9.80	20.16	....	77	101	107	215	......
New Mexico	18.48	18.75	15.18	16.40	....	118	163	166	175	......
Arizona	33.48	20.68	15.20	....	....	215	180	167	......	......
Utah	25.84	19.24	11.97	17.02	....	166	167	131	182	......
Nevada	33.66	....	....	16.80	....	216	......	......	179	......
Idaho	23.04	17.64	15.60	18.48	....	148	153	171	197	......
Pacific:										
Washington	21.56	13.42	11.02	20.28	....	138	117	121	217	......
Oregon	24.18	14.88	14.25	18.00	24.64	155	129	156	192	207
California	32.56	23.25	17.67	19.44	36.63	209	202	194	208	308

GEOGRAPHIC CHANGES IN SOURCES OF CORN SUPPLY AND OTHER PRICE FACTORS.

In conclusion, a statistical review from 1871 to 1915 is appended in Table 9, showing geographic changes in sources of the domestic corn supply, relation of production to population, and other factors.

Since 1871–1875 corn production has nearly trebled, but the fraction as well as quantity of corn exported has declined, likewise the percentage of shipments out of counties where grown. Consequently, the farm consumption has increased. Per capita production, however, has declined since 1882–1886 (31 bushels per capita against 28.5 in 1911–1915).

Notwithstanding the fact that the average production has increased from about 1 billion bushels at the first period to 2¾ billions at the last, the percentage of corn in the total improved land has fallen off. Increased crops are due to new areas which have been brought under cultivation rather than to an increased proportion of farm land devoted to corn.

Of the two corn-surplus divisions, the West North Central section has nearly quadrupled its production, while the crop of the East North Central States has less than doubled. The fraction of the national crop produced in the East North Central States has dropped from 38.8 per cent in 1871–1875 to 28.7 per cent in 1911–1915, while in the West North Central part in the same periods it has risen from 25.2 per cent to 35.9 per cent. A similar reversal obtains in hog production, which absorbs the largest quantity of corn in these two divisions. But, while the per cent of the total improved land occupied by corn has increased slightly in the older section, it has declined notably in the newer or western half. Moreover, in proportion to population (per capita production) in the more recent periods diminishing ratios are shown.

By far the highest percentage of increased production is shown in the Mountain States, wherein production has increased 347 per cent in the last decade (although per capita production has risen only from 2 bushels to 4.6 bushels). Secondary only to those of this section are the increased crops in the corn-deficiency States farthest to the south and north; on the south from South Carolina to Louisiana, and on the north from Washington to the Dakotas.

TABLE 9.—*Corn: A statistical review, from 1871 to 1915, by States and geographic divisions, showing changes in domestic sources of corn supply, in absolute and relative figures, trend of per capita production, and per cent of improved land in corn.*

State and geographic division.	Geographic distribution of corn production—in five-year averages.					Average 1911–1915 as compared with 1901–1905 (100 per cent).	Ratio of corn production to population.[1]					Distribution of corn production, in percentages of the United States totals.					Per cent of all improved land occupied by corn.[2]			
	1911–1915	1901–1905	1891–1895	1882–1886	1871–1875		1911–1915	1901–1905	1891–1895	1882–1886	1871–1875	1911–1915	1901–1905	1891–1895	1882–1886	1871–1875	1909	1899	1889	1879
	Thousand bushels.					*Per cent.*	*Number of bushels per capita.*					*Per cent.*					*Per cent.*			
United States	**2,766,112**	**2,293,164**	**1,734,468**	**1,713,047**	**1,037,622**	**121**	**28.5**	**28.4**	**25.9**	**31.0**	**24.7**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**20.6**	**22.9**	**20.2**	**21.9**
New England	9,059	6,764	7,043	8,136	7,613	134	1.3	1.2	1.4	1.9	2.1	0.3	0.3	0.4	0.5	0.7	2.5	2.4	1.5	1.8
Middle Atlantic	91,522	78,145	67,022	73,798	68,615	117	4.4	4.7	5.0	6.5	7.4	3.3	3.4	3.9	4.3	6.6	7.4	7.9	6.4	7.5
South Atlantic	263,312	191,384	159,028	143,646	100,232	138	20.6	17.4	17.0	17.7	15.7	9.5	8.3	9.2	8.4	9.7	23.5	26.1	23.1	26.8
East North Central	794,838	645,200	437,952	481,211	402,855	123	41.9	38.7	30.8	39.7	41.3	28.7	28.1	25.2	28.1	38.8	24.6	24.9	21.3	23.7
West North Central	992,756	900,726	709,528	674,864	261,115	110	82.3	83.9	75.8	92.9	57.4	35.9	39.3	40.9	39.4	25.2	21.9	26.2	26.7	29.0
East South Central	298,611	217,989	213,030	207,983	143,677	137	34.4	27.9	31.5	35.1	30.2	10.9	9.5	12.3	12.1	13.9	25.8	29.1	26.8	31.0
West South Central	298,651	246,615	134,130	117,430	50,665	121	31.4	34.2	25.4	30.1	20.9	10.8	10.8	7.7	6.9	4.9	25.6	28.1	18.3	23.8
Mountain	13,632	3,928	3,563	2,116	13	347	4.6	2.0	2.6	2.4	......	.5	.2	.2	.1	(3)	2.9	1.9	3.0	3.6
Pacific	3,731	2,413	3,172	3,863	1,490	155	.8	.8	1.6	2.7	1.8	.1	.1	.2	.2	.1	.4	.4	.5	.6
The Territories	......	......	......	......	1,347	......	......	......	......	......	......	......	......	......	......	.1	......	......	......	......
New England:																				
Maine	686	445	623	1,005	1,051	154	.9	.6	.9	1.5	1.7	(3)	(3)	(3)	.1	.1	.6	.7	.4	.9
New Hampshire	973	812	1,008	1,238	1,368	120	2.2	1.9	2.6	3.4	4.2	(3)	(3)	.1	.1	.1	2.1	2.4	1.4	1.6
Vermont	1,944	1,821	1,841	1,957	1,759	107	5.4	5.2	5.5	5.9	5.3	.1	.1	.1	.1	.2	2.6	2.9	1.6	1.7
Massachusetts	2,137	1,516	1,657	1,820	1,476	141	.6	.5	.7	.9	.9	.1	.1	.1	.1	.1	3.6	3.0	2.1	2.5
Rhode Island	466	312	308	384	294	149	.8	.7	.8	1.3	1.3	(3)	(3)	(3)	(3)	(3)	5.4	4.3	2.8	4.0
Connecticut	2,853	1,858	1,606	1,732	1,665	154	2.4	1.9	2.0	2.6	3.0	.1	.1	.1	.1	.2	5.3	4.5	2.9	3.4
Middle Atlantic:																				
New York	20,388	17,736	17,324	21,250	18,193	115	2.1	2.3	2.7	3.9	4.0	.7	.8	1.0	1.2	1.7	3.5	4.2	3.0	4.4
New Jersey	10,495	9,463	9,374	10,256	10,428	111	3.8	4.6	5.9	8.2	10.7	.4	.4	.6	.6	1.0	14.7	14.9	13.4	16.4
Pennsylvania	60,639	50,946	40,324	42,292	39,994	119	7.5	7.6	7.2	9.0	10.7	2.2	2.2	2.3	2.5	3.9	10.9	11.2	9.5	10.2
South Atlantic:																				
Delaware	6,635	5,511	4,495	3,900	3,186	120	31.9	29.0	26.0	25.0	24.1	.2	.2	.2	.2	.3	26.5	25.5	22.9	27.1
Maryland	24,080	20,793	15,545	16,086	11,383	116	18.1	17.0	14.3	16.4	13.8	.9	.9	.9	1.0	1.1	19.3	18.7	17.2	19.9
Virginia	49,292	41,681	32,318	31,377	19,485	118	23.2	21.8	18.8	20.0	14.9	1.8	1.8	1.9	1.8	1.9	18.8	18.9	17.5	20.8
West Virginia	22,652	19,283	15,315	14,428	9,723	117	17.3	18.6	18.6	21.3	19.6	.8	.8	.9	.9	.9	12.2	13.2	13.0	14.9
North Carolina	55,534	37,032	32,463	29,373	22,061	150	24.1	18.6	19.1	19.8	18.9	2.0	1.6	1.9	1.7	2.1	27.9	32.7	30.2	35.6
South Carolina	35,493	18,433	17,291	13,511	9,824	193	22.6	13.2	14.3	12.8	12.4	1.3	.8	1.0	.8	1.0	25.7	30.7	25.6	31.5
Georgia	59,401	42,724	36,363	31,103	22,507	139	21.7	18.3	18.6	18.7	17.4	2.1	1.9	2.1	1.8	2.2	27.5	32.8	26.9	30.9
Florida	10,225	5,927	5,238	3,868	2,063	173	12.4	9.9	12.1	12.2	9.7	.4	.3	.3	.2	.2	33.6	37.7	33.1	38.0

East North Central:																				
Ohio	153,991	100,409	81,438	92,068	92,140	153	31.0	23.1	21.3	27.2	32.6	5.6	4.4	4.7	5.4	8.9	20.4	19.9	17.4	18.2
Indiana	180,926	146,439	106,130	111,730	80,442	124	65.5	56.9	46.4	54.1	45.4	6.5	6.4	6.1	6.5	7.8	28.9	27.0	23.7	26.4
Illinois	343,924	312,287	197,003	221,897	195,647	110	58.3	61.6	47.8	65.7	72.4	12.4	13.6	11.3	12.9	18.8	35.8	37.1	30.6	34.5
Michigan	57,226	40,742	26,300	26,871	16,711	140	19.5	16.1	12.0	14.8	12.7	2.1	1.8	1.5	1.6	1.6	12.4	12.7	10.1	11.1
Wisconsin	58,771	45,323	27,081	28,645	17,915	130	24.3	21.1	15.0	19.5	15.8	2.1	1.9	1.6	1.7	1.7	12.2	13.3	11.4	11.1
West North Central:																				
Minnesota	80,283	40,231	25,154	19,644	7,643	200	36.8	21.8	17.4	19.8	14.1	2.9	1.8	1.3	1.2	.7	10.2	7.8	8.1	6.1
Iowa	353,619	273,064	236,556	207,812	116,386	130	159.1	122.5	117.8	119.4	88.0	12.8	11.9	13.6	12.1	11.2	31.3	32.8	29.8	33.3
Missouri	186,643	177,665	173,596	174,022	87,605	105	55.6	56.2	61.8	73.3	47.2	6.7	7.8	10.0	10.2	8.5	28.9	32.4	30.7	33.4
North Dakota	10,121	1,933	523	10,933	......	524	15.3	4.9	2.3	36.9	......	.4	.1	(3)	.6	......	.9	.6	.3	7.9
South Dakota	73,347	39,349	14,630			186	114.1	86.3	40.2			2.6	1.7	.8		......	12.9	10.6	10.8	
Nebraska	167,928	211,707	124,323	108,282	10,663	79	136.2	191.8	117.0	......	48.0	6.1	9.2	7.2	6.3	1.0	29.8	39.8	35.9	29.6
Kansas	120,815	156,777	134,746	154,171	38,818	77	68.5	102.0	93.5	131.9	70.1	4.4	6.8	7.8	9.0	3.8	27.1	33.0	32.8	31.8
East South Central:																				
Kentucky	96,623	80,785	76,288	80,982	56,908	120	41.4	36.9	39.2	46.8	40.1	3.5	3.5	4.4	4.7	5.5	23.9	24.2	25.0	28.2
Tennessee	84,599	70,319	71,734	70,813	45,055	120	37.8	34.0	38.9	43.4	33.5	3.1	3.1	4.1	4.1	4.4	28.9	32.9	29.8	34.2
Alabama	57,066	35,542	34,075	29,733	21,691	161	25.5	18.5	21.2	21.8	20.1	2.1	1.5	2.0	1.7	2.1	26.5	31.7	27.6	32.2
Mississippi	60,323	31,343	30,933	26,455	20,023	192	32.1	19.3	22.6	22.1	21.8	2.2	1.4	1.8	1.6	1.9	24.1	30.0	24.9	30.1
West South Central:																				
Louisiana	38,258	21,906	18,051	13,765	8,619	175	21.9	15.0	15.1	13.6	10.9	1.4	1.0	1.0	.8	.8	30.2	28.8	22.2	27.1
Texas	137,145	104,304	76,538	68,094	26,308	131	32.9	31.6	30.9	36.8	25.1	5.0	4.5	4.4	4.0	2.6	18.8	25.6	14.8	19.5
Oklahoma	72,983	[4] 79,560	......	......	......	92	37.6	[4] 75.7	......	......	......	2.6	[4] 3.5	......	......	......	33.7	[4] 29.2	2.4	......
Arkansas	50,265	40,845	39,541	35,571	15,738	123	30.3	29.4	33.4	38.1	27.1	1.8	1.8	2.3	2.1	1.5	28.2	33.3	30.1	36.1
Mountain:																				
Montana	1,077	83	31	19	(5)	1,298	2.6	.3	.2	.2	(5)	.1	(3)	(3)	(3)	(3)	.3	.2	.1	.1
Wyoming	441	62	53	......		711	2.7	.6	.7	1.4		(3)	(3)	(3)	......		.7	.2	.4	......
Colorado	8,433	2,231	2,380	712		378	9.6	3.6	5.3	2.5		.3	.1	.1	(3)		7.6	3.7	6.5	3.7
New Mexico	2,257	940	691	959		240	6.1	4.0	4.0	7.1		.1	(3)	(3)	.1		5.9	12.6	10.8	17.5
Arizona	535	175	95	61		306	2.3	1.2	1.0	1.0		(3)			(3)		4.5	4.6	4.2	3.2
Utah	350	292	282	305		120	.9	1.0	1.2	1.8							.5	1.1	1.1	2.9
Nevada	33	......	......	21	13	......	.3	......	......	.4	.3		......	......		(3)	.1	.1	(3)	.1
Idaho	506	145	31	39	(5)	349	1.3	.7	.3	.7	(5)		(3)	(3)		(5)	.3	.3	.2	.3
Pacific:																				
Washington	936	227	142	81	(5)	412	.7	.3	.4	.4	(5)	(3)	(3)	......	(3)	(5)	.4	.3	.5	.4
Oregon	723	419	312	150	92	173	1.0	.9	.9	.6	.8			(3)	(3)	(3)	.4	.5	.3	.3
California	2,072	1,767	2,718	3,632	1,398	117	.8	1.0	2.1	3.6	2.1	.1	.1	.2	.2	.1	.5	.5	.6	.7
The Territories	......	......	......	......	1,347	......	......	......	......	......	......	......	......	......	......	.1	......	......	......	......
United States	2,766,112	2,293,164	1,734,468	1,713,047	1,037,622	121	28.5	28.4	25.9	31.0	24.7	100.0	100.0	100.0	100.0	100.0	20.6	22.9	20.2	21.9
Domestic exports, including corn meal	38,774	74,615	63,980	49,398	38,561	52	.4	.9	1.0	.9	.9	1.4	3.3	3.7	2.9	3.7	......	......	......	......

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[1] Five-year averages, production divided by population. Average population calculated by prorating differences between census periods.

[2] From the decennial census returns.

[3] Less than one-tenth of 1 per cent.

[4] Includes Indian Territory.

[5] Included in "The Territories."

SUMMARY.

Local types of agriculture are established by a combination of physical and commercial limitations. Yields to the acre may be said to reflect limitations of climate and soil; the farm or producers' price is a result of commercial factors which vary with each item of farm production in a section. Moreover, such factors are dynamic in character.

Extreme geographic variations prevail in the farm price of a product throughout the United States. Prices rise in the direction taken by the flow of a commodity from the regions of surplus to those of deficient production. A region of high prices for one product may have decidedly low prices for another. Such variations are usually consistent and may be illustrated in corn prices.

Lowest prices are paid to producers of corn in the corn belt, from eastern Nebraska to western Ohio. The minimum price is found in the northwestern corner of this section, in adjoining parts of Iowa, Minnesota, South Dakota, and Nebraska. This area of minimum price forms a depression, moving away from which prices attain constantly higher levels to all points of the compass. The degree of price increase is unequal; slowest across through the corn belt, but more pronounced when the eastern States are reached. Westward and northward, where areas of scant production are close at hand, and where corn moves in smaller volume, price levels rise rapidly. This is also true farther to the south. The maximum prices are found in the Southwest and Southeast, in the sections producing insufficient corn which are farthest from the corn belt.

Within the territory of low corn prices are comprised the areas of greatest corn and live-stock production. They contribute almost the entire gross corn supply of the country and substantially all the corn entering trade channels. The minimum price obtains in the part of the corn belt which is most disadvantageously located with regard to important markets. All other sections produce less than their requirements and must supplement local crops by shipments from the surplus-producing country.

Prices rise irregularly in the direction of this distributive movement, which is somewhat complex. The trade currents are influenced by the manifold uses of corn, conditions in foreign and domestic live stock and grain markets, and the flexible character of the demand as expressed by variations in annual corn consumption. In tracing the geography of corn production in relation to prices, consumption, and commerce, notable regional differences are encountered. The bulk of the crop is consumed where it is produced—in the corn belt—for live-stock production; in the western half of the country hardly 2 per cent of the nation's crop is produced; and here, as in the most southern States, its high price and comparative scarcity limit its use for live-stock production. Throughout the country large local consuming centers of an industrial character have sprung up; in the New England States many million bushels are consumed in glucose and starch manufacture; a strong local demand for corn existed in Chicago, Indianapolis, St. Louis, and Peoria for use in manufacture of corn products and in distilling and brewing.

While a strongly defined greographic trend prevails in the price levels, much local unevenness is observable, as well as irregularity in the degree of increase. This is particularly manifest in regions which are mountainous, with inadequate transportation facilities or otherwise not well situated as to markets. It is also seen in areas wherein corn traffic is in smaller volume. In the midst of sections of insufficient production localities raising a surplus appear occasionally; the level of prices there is lower than in surrounding territory.

The outstanding feature of the distributive movement of corn is the local character of its markets, for only a fifth of the crop enters the national trade channels. Farm consumption absorbs over four-fifths of the crop; hence local conditions are partly responsible for much unevenness in the trend of the price levels. In some localities costs of hauling from farms to shipping points appear to be greater in time of peace than rail and ocean freight charges to some European markets. Diverse elements enter into local prices, such as the condition of roads, accessibility of markets, availability of cheaper water transportation, and the character of the local demand.

Although urban consumption disposes of only about a sixth of the crop, a considerably larger fraction is concentrated in urban markets for local use and reshipment. The largest markets are in the corn belt; they reship two-thirds of their receipts. Unlike wheat, markets for corn in other sections of the country are of minor importance.

Freight rates constitute the most important single element in price disparities. While distance is an important factor, rates are not directly proportional thereto. Competition between trade routes and markets, and volume of traffic, tend to lower rates in the sections affected.

In aligning sectional differences in farm prices with costs of production it is necessary to take into account yields to the acre. In the main, low farm prices are offset by high costs of production, and the converse also is true. High prices and high yields in bushels to the acre result in low money returns in the industrial East, because of high costs of production; high prices and low costs of production, but also low yields to the acre, result in relatively low money returns in the South.

Specific application of the maps and tables of this publication should take cognizance of the characteristics of the data. Counties are the units of measurement, and the figures represent customary conditions as determined by a five-year average. Prices reflect dynamic conditions. However, an unusual harvest or a market condition upsetting the ordinary course of business in a given product, will also disturb the price zones.

The normal price ratios, too, are slowly changing, in accord with economic conditions, of which they constitute an index. A review of price factors from 1871 to 1915 serves to indicate the present trend. While the United States average farm price of corn has risen, the geographic differences have been approximately cut in two, coinciding with decreasing transportation and marketing costs. In relation to the general average, the prices in corn-exporting States have risen rapidly and steadily; in corn-deficiency States the ratio has dropped even more notably. In some cases, notwithstanding the general rise in price levels, specific sections show declining prices as well as price percentages.

Corn and wheat prices are rapidly drawing closer. A 60-cent disparity in 1871–1875 has dwindled to 20 cents in 1911–1915. On the other hand, price disparity between corn and oats has widened because of the more rapid rise of corn prices.

The ramifications of price factors involve the entire economic structure. The charting of concrete geographic differences has possibilities of practical use. Presentation of only a few of the general bearings of the price conditions has been attempted here, for it has been manifestly impossible in this inquiry to enter into specific local surveys. It is also evident that no one factor determines the price zones, but each more or less determinate element is affected by others.

APPENDIX.

AVERAGE FARM PRICE OF CORN, BY COUNTIES, 1910–1914.

- Alabama:
  - 65 to 69 cents—
    - Jackson.
    - Lauderdale.
    - Limestone.
    - Madison.
  - 70 to 74 cents—
    - Colbert.
    - Dekalb.
    - Franklin.
    - Lawrence.
    - Marshall.
    - Morgan.
  - 80 to 84 cents—
    - Baldwin.
    - Blount.
    - Bullock.
    - Butler.
    - Calhoun.
    - Cherokee.
    - Choctaw.
    - Clarke.
    - Clay.
    - Cleburne.
    - Conecuh.
    - Crenshaw.
    - Cullman.
    - Dallas.
    - Escambia.
    - Etowah.
    - Greene.
    - Hale.
    - Lowndes.
    - Marengo.
    - Marion.
    - Mobile.
    - Monroe.
    - Montgomery.
    - Perry.
    - Sumter.
    - Talladega.
    - Washington.
    - Wilcox.
    - Winston.
  - 85 to 89 cents—
    - Autauga.
    - Barbour.
    - Bibb.
    - Chambers.
    - Chilton.
    - Coffee.
    - Coosa.
    - Covington.
    - Dale.
    - Elmore.
    - Fayette.
    - Geneva.
    - Henry.
    - Houston.
    - Jefferson.
    - Lamar.
    - Lee.
    - Macon.
    - Pickens.
    - Pike.
    - Randolph.
    - Russell.
    - St. Clair.
    - Shelby.
    - Tallapoosa.
    - Tuscaloosa.
    - Walker.
- Arizona:
  - 95 to 99 cents—
    - Cochise.
    - Graham.
    - Greenlee.
    - Maricopa.
    - Pima.
    - Pinal.
    - Santa Cruz.
  - $1 and over—
    - Apache.
    - Gila.
    - Navajo.
    - Yavapai.
- Arkansas:
  - 60 to 64 cents—
    - Benton.
    - Boone.
    - Carroll.
    - Madison.
    - Marion.
    - Washington.
  - 65 to 69 cents—
    - Baxter.
    - Clay.
    - Craighead.
    - Crawford.
    - Franklin.
    - Fulton.
    - Greene.
    - Johnson.
    - Lawrence.
    - Mississippi.
    - Newton.
    - Randolph.
    - Searcy.
    - Sharp.
    - Stone.
  - 70 to 74 cents—
    - Ashley.
    - Chicot.
    - Cleburne.
    - Conway.
    - Crittenden.
    - Cross.
    - Desha.
    - Drew.
    - Independence.
    - Izard.
    - Jackson.
    - Logan.
    - Montgomery.
    - Perry.
    - Poinsett.
    - Pope.
    - St. Francis.
    - Scott.
    - Sebastian.
    - Van Buren.
    - Yell.
  - 75 to 79 cents—
    - Arkansas.
    - Clark.
    - Cleveland.
    - Faulkner.
    - Garland.
    - Grant.
    - Hempstead.
    - Hot Spring.
    - Howard.
    - Jefferson.
    - Lafayette.
- Arkansas—Contd.
  - 75 to 79 cents—
    - Lee.
    - Lincoln.
    - Little River.
    - Lonoke.
    - Miller.
    - Monroe.
    - Phillips.
    - Pike.
    - Polk.
    - Prairie.
    - Pulaski.
    - Saline.
    - Sevier.
    - White.
    - Woodruff.
  - 80 to 84 cents—
    - Bradley.
    - Calhoun.
    - Columbia.
    - Dallas.
    - Nevada.
    - Ouachita.
    - Union.
- California:
  - 80 to 84 cents—
    - Kings.
    - Monterey.
    - San Diego.
    - San Luis Obispo.
    - Santa Cruz.
  - 85 to 89 cents—
    - Colusa.
    - Fresno.
    - Glenn.
    - Lake.
    - Los Angeles.
    - Marion.
    - Mendocino.
    - Napa.
    - Orange.
    - Sacramento.
    - San Joaquin.
    - Santa Barbara.
    - Sonoma.
    - Tulare.
    - Ventura.
- Colorado:
  - 60 to 64 cents—
    - Logan.
    - Phillips.
    - Sedgwick.
    - Yuma.
  - 65 to 69 cents—
    - Baca.
    - Bent.
    - Cheyenne.
    - Kiowa.
    - Kit Carson.
    - Lincoln.
    - Morgan.
    - Prowers.
    - Washington.
  - 70 to 74 cents—
    - Adams.
    - Arapahoe.
    - Boulder.
    - Custer.
    - Denver.
    - Douglas.
    - Elbert.
- Colorado—Continued.
  - 70 to 74 cents—
    - El Paso.
    - Gilpin.
    - Huerfano.
    - Jefferson.
    - Larimer.
    - Las Animas.
    - Otero.
    - Pueblo.
    - Washington.
    - Weld.
  - 90 to 94 cents—
    - Delta.
    - Mesa.
- Connecticut:
  - 80 to 84 cents—
    - Hartford.
    - Middlesex.
    - New Haven.
    - New London.
    - Tolland.
    - Windham.
  - 85 to 89 cents—
    - Fairfield.
    - Litchfield.
- Delaware:
  - 60 to 64 cents—
    - Kent.
    - New Castle.
    - Sussex.
- Florida:
  - 80 to 84 cents—
    - Calhoun.
    - Columbia.
    - Franklin.
    - Gadsden.
    - Hamilton.
    - Jackson.
    - Jefferson.
    - Leon.
    - Liberty.
    - Madison.
    - Suwanee.
    - Wakulla.
  - 85 to 89 cents—
    - Alachua.
    - Escambia.
    - Holmes.
    - Lafayette.
    - Levy.
    - Marion.
    - Putnam.
    - St. John.
    - Santa Rosa.
    - Taylor.
    - Walton.
    - Washington.
  - 90 to 94 cents—
    - Baker.
    - Bradford.
    - Citrus.
    - Clay.
    - De Soto.
    - Duval.
    - Hernando.
    - Hillsboro.
    - Lake.
    - Manatee.
    - Nassau.
    - Orange.
    - Osceola.

Florida—Continued.
  90 to 94 cents—
    Pasco.
    Pinellas.
    Polk.
    Sumter.
    Volusia.
Georgia:
  75 to 79 cents—
    Catoosa.
    Dade.
    Fannin.
    Gilmer.
    Murray.
    Rabun.
    Towns.
    Union.
    Walker.
    Whitfield.
  80 to 84 cents—
    Baker.
    Bartow.
    Brooks.
    Calhoun.
    Chattooga.
    Cherokee.
    Clay.
    Colquitt.
    Dawson.
    Decatur.
    Dougherty.
    Early.
    Floyd.
    Forsyth.
    Gordon.
    Grady.
    Habersham.
    Lee.
    Lumpkin.
    Miller.
    Milton.
    Mitchell.
    Pickens.
    Polk.
    Quitman.
    Randolph.
    Stewart.
    Terrell.
    Thomas.
    Webster.
    White.
    Worth.
  85 to 89 cents—
    Banks.
    Ben Hill.
    Berrien.
    Bibb.
    Bleckley.
    Campbell.
    Carroll.
    Chattahoochee.
    Clayton.
    Clinch.
    Cobb.
    Coffee.
    Coweta.
    Crawford.
    Crisp.
    Dekalb.
    Dodge.
    Dooly.
    Douglas.
    Echols.
    Fayette.
    Franklin.
    Fulton.
    Gwinnett.
    Hall.
    Haralson.
    Harris.
    Heard.
    Henry.
    Houston.
    Irwin.
    Lowndes.
    Macon.
    Marion.
    Meriwether.
    Monroe.

Georgia—Continued.
  85 to 89 cents—
    Muscogee.
    Newton.
    Paulding.
    Pike.
    Pulaski.
    Rockdale.
    Schley.
    Spaulding.
    Stephens.
    Sumter.
    Talbot.
    Taylor.
    Tift.
    Troop.
    Turner.
    Twiggs.
    Upson.
    Wilcox.
    Wilkinson.
  90 to 94 cents—
    Appling.
    Baldwin.
    Bryan.
    Bulloch.
    Burke.
    Butts.
    Camden.
    Charlton.
    Chatham.
    Clarke.
    Columbia.
    Effingham.
    Elbert.
    Emanuel.
    Glascock.
    Glynn.
    Greene.
    Hancock.
    Hart.
    Jackson.
    Jasper.
    Jeff Davis.
    Jefferson.
    Jenkins.
    Johnson.
    Jones.
    Laurens.
    Liberty.
    Lincoln.
    McDuffie.
    McIntosh.
    Madison.
    Montgomery.
    Morgan.
    Oconee.
    Oglethorpe.
    Pierce.
    Putnam.
    Richmond.
    Screven.
    Taliaferro.
    Tattnall.
    Telfair.
    Toombs.
    Walton.
    Ware.
    Warren.
    Washington.
    Wayne.
    Wheeler.
    Wilkes.
Idaho:
  65 to 69 cents—
    Canyon.
    Latah.
    Nez Perce.
Illinois:
  50 to 54 cents—
    Bureau.
    Carroll.
    Champaign.
    Christian.
    Clark.
    Coles.
    Crawford.
    Cumberland.
    Dekalb.

Illinois—Continued.
  50 to 54 cents—
    Dewitt.
    Douglas.
    Edgar.
    Edwards.
    Ford.
    Gallatin.
    Grundy.
    Hancock.
    Henderson.
    Henry.
    Iroquois.
    Jasper.
    Kankakee.
    Knox.
    La Salle.
    Lawrence.
    Lee.
    Livingston.
    Logan.
    McDonough.
    McLean.
    Macon.
    Marshall.
    Mason.
    Menard.
    Mercer.
    Morgan.
    Moultrie.
    Ogle.
    Peoria.
    Piatt.
    Putnam.
    Richland.
    Rock Island.
    Sangamon.
    Scott.
    Shelby.
    Stark.
    Tazewell.
    Vermilion.
    Wabash.
    Warren.
    White.
    Whiteside.
    Woodford.
  55 to 59 cents—
    Adams.
    Alexander.
    Bond.
    Boone.
    Brown.
    Calhoun.
    Cass.
    Clay.
    Effingham.
    Fayette.
    Fulton.
    Greene.
    Hamilton.
    Hardin.
    Jackson.
    Jersey.
    Jo Daviess.
    Johnson.
    Kane.
    Kendall.
    McHenry.
    Macoupin.
    Marion.
    Massac.
    Montgomery.
    Pike.
    Pope.
    Pulaski.
    Saline.
    Schuyler.
    Stephenson.
    Union.
    Wayne.
    Will.
    Winnebago.
  60 to 64 cents—
    Clinton.
    Cook.
    Dupage.
    Franklin.
    Jefferson.

Illinois—Continued.
  60 to 64 cents—
    Lake.
    Monroe.
    Perry.
    Randolph.
    Washington.
    Williamson.
Indiana:
  50 to 54 cents—
    Adams.
    Allen.
    Bartholomew.
    Benton.
    Blackford.
    Boone.
    Brown.
    Carroll.
    Cass.
    Clay.
    Clinton.
    Daviess.
    Decatur.
    Dekalb.
    Delaware.
    Elkhart.
    Fayette.
    Fountain.
    Franklin.
    Fulton.
    Gibson.
    Grant.
    Greene.
    Hamilton.
    Hancock.
    Hendricks.
    Henry.
    Howard.
    Huntington.
    Jasper.
    Jay.
    Jennings.
    Johnson.
    Knox.
    Kosciusko.
    Lagrange.
    Laporte.
    Madison.
    Marion.
    Marshall.
    Miami.
    Monroe.
    Montgomery.
    Morgan.
    Newton.
    Noble.
    Owen.
    Parke.
    Porter.
    Posey.
    Pulaski.
    Putnam.
    Randolph.
    Rush.
    St. Joseph.
    Shelby.
    Starke.
    Steuben.
    Sullivan.
    Tippecanoe.
    Tipton.
    Union.
    Vermilion.
    Vigo.
    Wabash.
    Warren.
    Wayne.
    Wells.
    White.
    Whitley.
  55 to 59 cents—
    Clarke.
    Dearborn.
    Dubois.
    Jackson.
    Jefferson.
    Lake.
    Lawrence.
    Martin.

- Indiana—Continued.
  - 55 to 59 cents—
    - Ohio.
    - Pike.
    - Ripley.
    - Scott.
    - Spencer.
    - Switzerland.
    - Vanderburg.
    - Warrick.
  - 60 to 64 cents—
    - Crawford.
    - Floyd.
    - Harrison.
    - Orange.
    - Perry.
    - Washington.
- Iowa:
  - 45 to 49 cents—
    - Audubon.
    - Boone.
    - Bremer.
    - Buena Vista.
    - Butler.
    - Calhoun.
    - Carroll.
    - Cerro Gordo.
    - Cherokee.
    - Chickasaw.
    - Clay.
    - Crawford.
    - Dallas.
    - Dickinson.
    - Emmet.
    - Floyd.
    - Franklin.
    - Greene.
    - Grundy.
    - Guthrie.
    - Hamilton.
    - Hancock.
    - Hardin.
    - Harrison.
    - Humbolt.
    - Ida.
    - Jasper.
    - Kossuth.
    - Lyon.
    - Marshall.
    - Monona.
    - O'Brien.
    - Osceola.
    - Palo Alto.
    - Plymouth.
    - Pocahontas.
    - Polk.
    - Sac.
    - Shelby.
    - Sioux.
    - Story.
    - Webster.
    - Winnebago.
    - Woodbury.
    - Worth.
    - Wright.
  - 50 to 64 cents—
    - Adair.
    - Adams.
    - Allamakee.
    - Appanoose.
    - Benton.
    - Blackhawk.
    - Buchanan.
    - Cass.
    - Cedar.
    - Clarke.
    - Clayton.
    - Davis.
    - Decatur.
    - Delaware.
    - Des Moines.
    - Fayette.
    - Fremont.
    - Henry.
    - Howard.
    - Iowa.
- Iowa—Continued.
  - 50 to 64 cents—
    - Jefferson.
    - Johnson.
    - Keokuk.
    - Lee.
    - Linn.
    - Louisa.
    - Lucas.
    - Madison.
    - Mahaska.
    - Marion.
    - Mills.
    - Mitchell.
    - Monroe.
    - Montgomery.
    - Muscatine.
    - Page.
    - Pottawattamie.
    - Poweshiek.
    - Ringgold.
    - Scott.
    - Tama.
    - Taylor.
    - Union.
    - Van Buren.
    - Wapello.
    - Warren.
    - Washington.
    - Wayne.
    - Winneshiek.
  - 55 to 59 cents—
    - Clinton.
    - Dubuque.
    - Jackson.
    - Jones.
- Kansas:
  - 55 to 59 cents—
    - Allen.
    - Anderson.
    - Atchison.
    - Bourbon.
    - Brown.
    - Clay.
    - Cloud.
    - Coffey.
    - Crawford.
    - Dickinson.
    - Doniphan.
    - Douglas.
    - Franklin.
    - Geary.
    - Jackson.
    - Jefferson.
    - Jewell.
    - Johnson.
    - Leavenworth.
    - Linn.
    - Lyon.
    - Marshall.
    - Miami.
    - Morris.
    - Nemaha.
    - Neosho.
    - Osage.
    - Phillips.
    - Pottawatomie.
    - Republic.
    - Riley.
    - Shawnee.
    - Smith.
    - Wabaunsee.
    - Washington.
    - Wilson.
    - Woodson.
    - Wyandotte.
  - 60 to 64 cents—
    - Barber.
    - Barton.
    - Butler.
    - Chase.
    - Chautauqua.
    - Cherokee.
    - Cheyenne.
    - Clark.
    - Comanche.
- Kansas—Continued.
  - 60 to 64 cents—
    - Cowley.
    - Decatur.
    - Edwards.
    - Elk.
    - Ellsworth.
    - Ford.
    - Graham.
    - Gray.
    - Greenwood.
    - Harper.
    - Harvey.
    - Hodgeman.
    - Kingman.
    - Kiowa.
    - Labette.
    - Lincoln.
    - McPherson.
    - Marion.
    - Meade.
    - Mitchell.
    - Montgomery.
    - Norton.
    - Osborne.
    - Ottawa.
    - Pawnee.
    - Pratt.
    - Rawlins.
    - Reno.
    - Rice.
    - Rooks.
    - Russell.
    - Saline.
    - Sedgwick.
    - Seward.
    - Sheridan.
    - Sherman.
    - Stafford.
    - Stevens.
    - Sumner.
    - Thomas.
  - 65 to 69 cents—
    - Ellis.
    - Finney.
    - Gove.
    - Grant.
    - Greeley.
    - Hamilton.
    - Haskell.
    - Kearny.
    - Lane.
    - Logan.
    - Morton.
    - Ness.
    - Rush.
    - Scott.
    - Trego.
    - Wallace.
    - Wichita.
- Kentucky:
  - 55 to 59 cents—
    - Ballard.
    - Caldwell.
    - Carlisle.
    - Crittenden.
    - Daviess.
    - Fulton.
    - Graves.
    - Hancock.
    - Henderson.
    - Hickman.
    - Hopkins.
    - Livingston.
    - Lyon.
    - McCracken.
    - McLean.
    - Union.
    - Webster.
  - 60 to 64 cents—
    - Adair.
    - Allen.
    - Barren.
    - Boone.
    - Bourbon.
    - Boyle.
- Kentucky—Contd.
  - 60 to 64 cents—
    - Breckinridge.
    - Bullitt.
    - Butler.
    - Calloway.
    - Carroll.
    - Casey.
    - Christian.
    - Clark.
    - Clinton.
    - Cumberland.
    - Edmonson.
    - Estill.
    - Fayette.
    - Gallatin.
    - Garrard.
    - Grayson.
    - Green.
    - Greenup.
    - Hardin.
    - Hart.
    - Jessamine.
    - Larue.
    - Lewis.
    - Lincoln.
    - Logan.
    - Madison.
    - Marion.
    - Marshall.
    - Meade.
    - Mercer.
    - Metcalf.
    - Monroe.
    - Muhlenberg.
    - Nelson.
    - Ohio.
    - Rock Castle.
    - Russell.
    - Scott.
    - Simpson.
    - Spencer.
    - Taylor.
    - Todd.
    - Trigg.
    - Trimble.
    - Warren.
    - Washington.
    - Woodford.
  - 65 to 69 cents—
    - Anderson.
    - Bath.
    - Boyd.
    - Bracken.
    - Campbell.
    - Carter.
    - Elliott.
    - Fleming.
    - Franklin.
    - Grant.
    - Harrison.
    - Henry.
    - Jefferson.
    - Johnson.
    - Kenton.
    - Lawrence.
    - Mason.
    - Menifee.
    - Montgomery.
    - Nicholas.
    - Oldham.
    - Owen.
    - Pendleton.
    - Powell.
    - Robertson.
    - Rowan.
    - Shelby.
  - 70 to 74 cents—
    - Bell.
    - Breathitt.
    - Clay.
    - Floyd.
    - Jackson.
    - Knox.
    - Laurel.
    - Lee.

- Kentucky—Contd.
  - 70 to 74 cents—
    - McCreary.
    - Magoffin.
    - Martin.
    - Morgan.
    - Owsley.
    - Pulaski.
    - Wayne.
    - Whitley.
    - Wolfe.
  - 75 to 79 cents—
    - Harlan.
    - Knott.
    - Leslie.
    - Letcher.
    - Perry.
    - Pike.
- Louisiana:
  - 65 to 69 cents—
    - Ascension.
    - Assumption.
    - Avoyelles.
    - Iberia.
    - Iberville.
    - Lafayette.
    - Pointe Coupee.
    - St. Landry.
    - St. Martin.
    - St. Mary.
    - West Baton Rouge
    - West Feliciana.
  - 70 to 74 cents—
    - Catahoula.
    - Concordia.
    - East Baton Rouge.
    - East Carroll.
    - East Feliciana.
    - Franklin.
    - Grant.
    - Jefferson.
    - Lafourche.
    - La Salle.
    - Livingston.
    - Madison.
    - Morehouse.
    - Orleans.
    - Plaquemines.
    - Richland.
    - St. Bernard.
    - St. Charles.
    - St. Helena.
    - St. James.
    - St. John.
    - Tensas.
    - Terrebonne.
    - West Carroll.
  - 75 to 79 cents—
    - Acadia.
    - Bossier.
    - Caddo.
    - Caldwell.
    - De Soto.
    - Evangeline.
    - Natchitoches.
    - Ouachita.
    - Rapides.
    - Red River.
    - St. Tammany.
    - Tangipahoa.
    - Vermilion.
    - Washington.
    - Winn.
  - 80 to 84 cents—
    - Allen.
    - Beauregard.
    - Bienville.
    - Calcasieu.
    - Cameron.
    - Claiborne.
    - Jackson.
    - Jefferson Davis.
    - Lincoln.
    - Sabine.
    - Union.
    - Vernon.
    - Webster.
- Maryland:
  - 60 to 64 cents—
    - Baltimore.
    - Caroline.
    - Carroll.
    - Cecil.
    - Dorchester.
    - Frederick.
    - Harford.
    - Howard.
    - Kent.
    - Montgomery.
    - Queen Annes.
    - Somerset.
    - Talbot.
    - Washington.
    - Wicomico.
    - Worcester.
  - 65 to 69 cents—
    - Anne Arundel.
    - Calvert.
    - Charles.
    - Prince George.
    - St. Marys.
  - 75 to 79 cents—
    - Allegany.
    - Garrett.
- Massachusetts:
  - 80 to 84 cents—
    - Berkshire.
    - Essex.
    - Franklin.
    - Hampden.
    - Hampshire.
    - Middlesex.
    - Norfolk.
    - Suffolk.
    - Worcester.
  - 85 to 89 cents—
    - Barnstable.
    - Bristol.
    - Dukes.
    - Nantucket.
    - Plymouth.
- Michigan:
  - 55 to 59 cents—
    - Berrien.
    - Branch.
    - Cass.
    - Hillsdale.
    - Kalamazoo.
    - Lenawee.
    - Monroe.
    - St. Joseph.
    - Van Buren.
  - 60 to 64 cents—
    - Allegan.
    - Barry.
    - Benzie.
    - Calhoun.
    - Clare.
    - Clinton.
    - Eaton.
    - Gratiot.
    - Ingham.
    - Ionia.
    - Isabella.
    - Jackson.
    - Kent.
    - Lake.
    - Livingston.
    - Manistee.
    - Mason.
    - Mecosta.
    - Missaukee.
    - Montcalm.
    - Osceola.
    - Shiwassee.
    - Washtenaw.
    - Wayne.
    - Wexford.
  - 65 to 69 cents—
    - Alcona.
    - Alpena.
    - Antrim.
    - Arenac.
    - Bay.
- Michigan—Contd.
  - 65 to 69 cents—
    - Crawford.
    - Genesee.
    - Gladwin.
    - Grand Traverse.
    - Huron.
    - Iosco.
    - Kalkaska.
    - Lapeer.
    - Leelanau.
    - Macomb.
    - Midland.
    - Muskegon.
    - Newaygo.
    - Oakland.
    - Oceana.
    - Ogemaw.
    - Otsego.
    - Ottawa.
    - Roscommon.
    - Saginaw.
    - St. Clair.
    - Sanilac.
    - Tuscola.
  - 70 to 74 cents—
    - Charlevoix.
    - Cheboygan.
    - Emmet.
- Minnesota:
  - 45 to 49 cents—
    - Bigstone.
    - Blue Earth.
    - Brown.
    - Chippewa.
    - Cottonwood.
    - Faribault.
    - Freeborn.
    - Jackson.
    - Kandiyohi.
    - Lac qui Parle.
    - Le Sueur.
    - Lincoln.
    - Lyon.
    - McLeod.
    - Martin.
    - Murray.
    - Nicollet.
    - Nobles.
    - Pipestone.
    - Redwood.
    - Renville.
    - Rice.
    - Rock.
    - Sibley.
    - Steele.
    - Swift.
    - Waseca.
    - Watonwan.
    - Yelloy Medicine.
  - 50 to 54 cents—
    - Anoka.
    - Benton.
    - Carver.
    - Dakota.
    - Dodge.
    - Douglas.
    - Fillmore.
    - Goodhue.
    - Grant.
    - Houston.
    - Isanti.
    - Meeker.
    - Mower.
    - Olmsted.
    - Ottertail.
    - Pope.
    - Scott.
    - Sherbourne.
    - Stearns.
    - Stevens.
    - Traverse.
    - Wabasha.
    - Wilkin.
    - Winona.
    - Wright.
- Minnesota—Contd.
  - 55 to 59 cents—
    - Becker.
    - Chisago.
    - Clay.
    - Hennepin.
    - Hubbard.
    - Kanabec.
    - Mille Lacs.
    - Morrison.
    - Norman.
    - Pine.
    - Ramsey.
    - Todd.
    - Wadena.
    - Washington.
  - 60 to 64 cents—
    - Aitkin.
    - Beltrami.
    - Cass.
    - Clearwater.
    - Crow Wing.
    - Kittson.
    - Mahnomen.
    - Marshall.
    - Pennington.
    - Polk.
    - Red Lake.
    - Roseau.
- Mississippi:
  - 65 to 69 cents—
    - Adams.
    - Amite.
    - Claiborne.
    - Franklin.
    - Issaquena.
    - Jefferson.
    - Sharkey.
    - Warren.
    - Wilkinson.
  - 70 to 74 cents—
    - Alcorn.
    - Benton.
    - Bolivar.
    - Copiah.
    - De Soto.
    - Hinds.
    - Holmes.
    - Lincoln.
    - Madison.
    - Marshall.
    - Pike.
    - Prentiss.
    - Sunflower.
    - Tippah.
    - Tishomingo.
    - Union.
    - Washington.
    - Yazoo.
  - 75 to 79 cents—
    - Attala.
    - Calhoun.
    - Carroll.
    - Chickasaw.
    - Choctaw.
    - Clay.
    - Coahoma.
    - Grenada.
    - Itawamba.
    - Jefferson Davis.
    - Lafayette.
    - Lawrence.
    - Leake.
    - Lee.
    - Leflore.
    - Marion.
    - Montgomery.
    - Oktibbeha.
    - Panola.
    - Pontotoc.
    - Quitman.
    - Rankin.
    - Scott.
    - Simpson.
    - Tallahatchie.
    - Tate.
    - Tunica.

Mississippi—Contd.
75 to 79 cents—
Webster.
Winston.
Yalobusha.
80 to 84 cents—
Clarke.
Covington.
Forrest.
George.
Greene.
Hancock.
Harrison.
Jackson.
Jasper.
Jones.
Kemper.
Lamar.
Lauderdale.
Lowndes.
Monroe.
Neshoba.
Newton.
Pearl River.
Perry.
Smith.
Wayne.
Missouri:
50 to 54 cents—
Atchison.
55 to 59 cents—
Adair.
Andrew.
Audrain.
Barton.
Bates.
Buchanan.
Caldwell.
Cape Girardeau.
Carroll.
Cass.
Chariton.
Clark.
Clay.
Clinton.
Daviess.
Dekalb.
Dunklin.
Gentry.
Grundy.
Harrison.
Holt.
Howard.
Jackson.
Knox.
Lewis.
Linn.
Livingston.
Macon.
Marion.
Mercer.
Mississippi.
Monroe.
New Madrid.
Nodaway.
Pemiscot.
Pike.
Platte.
Putnam.
Ralls.
Randolph.
Ray.
Schuyler.
Scotland.
Scott.
Shelby.
Sullivan.
Vernon.
Worth.
60 to 64 cents—
Barry.
Benton.
Bollinger.
Boone.
Butler.
Callaway.
Cedar.
Christian.
Cooper.

Missouri—Continued.
60 to 64 cents—
Dade.
Greene.
Henry.
Jasper.
Jefferson.
Johnson.
Lafayette.
Lawrence.
Lincoln.
McDonald.
Madison.
Moniteau.
Montgomery.
Morgan.
Newton.
Perry.
Pettis.
Polk.
St. Charles.
St. Clair.
St. Francois.
Saline.
Stoddard.
Stone.
Warren.
65 to 69 cents—
Camden.
Carter.
Cole.
Crawford.
Dallas.
Dent.
Douglas.
Franklin.
Gasconade.
Hickory.
Iron.
Laclede.
Maries.
Miller.
Oregon.
Osage.
Ozark.
Ripley.
St. Louis.
Taney.
Washington.
Wayne.
Webster.
Wright.
70 to 74 cents—
Howell.
Phelps.
Pulaski.
Reynolds.
Shannon.
Texas.
Nebraska:
45 to 49 cents—
Antelope.
Blaine.
Boone.
Boyd.
Brown.
Burt.
Cedar.
Colfax.
Cuming.
Dakota.
Dixon.
Dodge.
Garfield.
Holt.
Keyapaha.
Knox.
Loup.
Madison.
Nance.
Pierce.
Platte.
Rock.
Stanton.
Thurston.
Washington.
Wayne.
Wheeler.

Nebraska—Contd.
50 to 54 cents—
Adams.
Buffalo.
Butler.
Cass.
Cherry.
Clay.
Custer.
Dawson.
Douglas.
Fillmore.
Franklin.
Frontier.
Gage.
Garden.
Gosper.
Grant.
Greeley.
Hall.
Hamilton.
Hayes.
Hooker.
Howard.
Jefferson.
Johnson.
Kearney.
Lancaster.
Lincoln.
Logan.
McPherson.
Merrick.
Nemaha.
Nuckolls.
Otoe.
Pawnee.
Phelps.
Polk.
Richardson.
Saline.
Sarpy.
Saunders.
Seward.
Sherman.
Thayer.
Thomas.
Valley.
Webster.
York.
55 to 59 cents—
Boxbutte.
Chase.
Cheyenne.
Dawes.
Deuel.
Dundy.
Furnas.
Harlan.
Hitchcock.
Perkins.
Redwillow.
Sheridan.
60 to 64 cents—
Banner.
Kimball.
Scottsbluff.
Sioux.
New Hampshire:
75 to 79 cents—
Hillsboro.
Rockingham.
80 to 84 cents—
Belknap.
Carroll.
Cheshire.
Coos.
Grafton.
Merrimack.
Strafford.
Sullivan.
New Jersey:
70 to 74 cents—
Burlington.
Camden.
Gloucester.
Hunterdon.
Mercer.
Middlesex.

New Jersey—Contd.
70 to 74 cents—
Monmouth.
Morris.
Salem.
Somerset.
Union.
Warren.
75 to 79 cents—
Atlantic.
Bergen.
Cape May.
Cumberland.
Essex.
Hudson.
Ocean.
Passaic.
Sussex.
New Mexico:
75 to 79 cents—
Curry.
Quay.
Roosevelt.
Union.
85 to 89 cents—
Chaves.
Colfax.
Eddy.
Guadalupe.
Lincoln.
Mora.
Otero.
San Miguel.
Taos.
Torrence.
95 to 99 cents—
Bernalillo.
Dona Ana.
Grant.
Luna.
McKinley.
Rio Arriba.
Sandoval.
San Juan.
Santa Fe.
Sierra.
Socorro.
Valencia.
New York:
70 to 74 cents—
Allegany.
Broome.
Cattaraugus.
Chautauqua.
Chemung.
Cortland.
Erie.
Genesee.
Livingston.
Niagara.
Orleans.
Schuyler.
Steuben.
Tioga.
Tompkins.
Wyoming.
75 to 79 cents—
Cayuga.
Chenango.
Delaware.
Franklin.
Jefferson.
Lewis.
Madison.
Monroe.
Oneida.
Onondaga.
Ontario.
Orange.
Oswego.
Rockland.
St. Lawrence.
Seneca.
Sullivan.
Wayne.
Westchester.
Yates.

New York—Contd.
- 80 to 84 cents—
  - Albany.
  - Clinton.
  - Columbia.
  - Dutchess.
  - Essex.
  - Fulton.
  - Greene.
  - Hamilton.
  - Herkimer.
  - Kings.
  - Montgomery.
  - Nassau.
  - Otsego.
  - Putnam.
  - Queens.
  - Rensselaer.
  - Richmond.
  - Saratoga.
  - Schenectady.
  - Schoharie.
  - Suffolk.
  - Ulster.
  - Warren.
  - Washington,

North Carolina:
- 75 to 79 cents—
  - Alexander.
  - Buncombe.
  - Burke.
  - Caldwell.
  - Davie.
  - Haywood.
  - Iredell.
  - McDowell.
  - Madison.
  - Yadkin.
- 80 to 84 cents—
  - Cherokee.
  - Clay.
  - Graham.
  - Henderson.
  - Jackson.
  - Macon.
  - Polk.
  - Rutherford.
  - Swain.
  - Transylvania.
- 85 to 89 cents—
  - Alamance.
  - Alleghany.
  - Ashe.
  - Avery.
  - Beaufort.
  - Bertie.
  - Cabarrus.
  - Camden.
  - Caswell.
  - Catawba.
  - Chatham.
  - Chowan.
  - Cleveland.
  - Craven.
  - Currituck.
  - Dare.
  - Davidson.
  - Durham.
  - Edgecombe.
  - Forsyth.
  - Gaston.
  - Gates.
  - Granville.
  - Greene.
  - Guilford.
  - Halifax.
  - Hertford.
  - Hyde.
  - Lenoir.
  - Lincoln.
  - Martin.
  - Mecklenburg.
  - Mitchell.
  - Northampton.
  - Orange.
  - Pamlico.
  - Pasquotank.
  - Perquimans.
  - Person.

North Carolina—Con.
- 85 to 89 cents—
  - Pitt.
  - Randolph.
  - Rockingham.
  - Rowan.
  - Stokes.
  - Surry.
  - Tyrrell.
  - Vance.
  - Warren.
  - Washington.
  - Watauga.
  - Wayne.
  - Wilkes.
  - Yancy.
- 90 to 94 cents—
  - Anson.
  - Carteret.
  - Cumberland.
  - Duplin.
  - Franklin.
  - Harnett.
  - Hoke.
  - Johnston.
  - Jones.
  - Lee.
  - Montgomery.
  - Moore.
  - Nash.
  - Onslow.
  - Sampson.
  - Stanly.
  - Union.
  - Wake.
  - Wilson.
- 95 to 99 cents—
  - Bladen.
  - Brunswick.
  - Columbus.
  - New Hanover.
  - Pender.
  - Richmond.
  - Robeson.
  - Scotland.

North Dakota:
- 50 to 54 cents—
  - Cass.
  - Ransom.
  - Richmond.
  - Sargent.
- 55 to 59 cents—
  - Barnes.
  - Burleigh.
  - Cavalier.
  - Dickey.
  - Emmons.
  - Grand Forks.
  - Kidder.
  - Lamoure.
  - Logan.
  - McIntosh.
  - Nelson.
  - Pembina.
  - Ramsey.
  - Steele.
  - Stutsman.
  - Towner.
  - Traill.
  - Walsh.
- 60 to 64 cents—
  - Adams.
  - Dunn.
  - Hettinger.
  - McLean.
  - Mercer.
  - Morton.
  - Oliver.
  - Stark.

Ohio:
- 50 to 54 cents—
  - Allen.
  - Auglaize.
  - Champaign.
  - Clark.
  - Darke.
  - Defiance.
  - Delaware.
  - Fayette.

Ohio—Continued.
- 50 to 54 cents—
  - Franklin.
  - Fulton.
  - Greene.
  - Hancock.
  - Hardin.
  - Henry.
  - Logan.
  - Madison.
  - Marion.
  - Mercer.
  - Miami.
  - Paulding.
  - Preble.
  - Putnam.
  - Shelby.
  - Union.
  - Van Wert.
  - Williams.
  - Wood.
  - Wyandot.
- 55 to 59 cents—
  - Ashland.
  - Butler.
  - Clinton.
  - Crawford.
  - Fairfield.
  - Highland.
  - Huron.
  - Knox.
  - Licking.
  - Lucas.
  - Montgomery.
  - Morrow.
  - Ottawa.
  - Pickaway.
  - Pike.
  - Richland.
  - Ross.
  - Sandusky.
  - Senaca.
  - Warren.
- 60 to 64 cents—
  - Adams.
  - Brown.
  - Clermont.
  - Coshocton.
  - Erie.
  - Gallia.
  - Hamilton.
  - Hocking.
  - Holmes.
  - Jackson.
  - Lawrence.
  - Lorain.
  - Medina.
  - Muskingum.
  - Perry.
  - Scioto.
  - Vinton.
  - Wayne.
- 65 to 69 cents—
  - Ashtabula.
  - Athens.
  - Belmont.
  - Carroll.
  - Columbiana.
  - Cuyahoga.
  - Geauga.
  - Guernsey.
  - Harrison.
  - Jefferson.
  - Lake.
  - Mahoning.
  - Meigs.
  - Monroe.
  - Morgan.
  - Noble.
  - Portage.
  - Stark.
  - Summit.
  - Trumbull.
  - Tuscarawas.
  - Washington.

Oklahoma:
- 55 to 59 cents—
  - Beckham.
  - Blaine.

Oklahoma—Contd.
- 55 to 59 cents—
  - Caddo.
  - Custer.
  - Dewey.
  - Ellis.
  - Roger Mills.
  - Washita.
- 60 to 64 cents—
  - Adair.
  - Alfalfa.
  - Beaver.
  - Canadian.
  - Cherokee.
  - Cimarron.
  - Cleveland.
  - Comanche.
  - Cotton.
  - Craig.
  - Delaware.
  - Garfield.
  - Garvin.
  - Grady.
  - Grant.
  - Greer.
  - Harmon.
  - Harper.
  - Jackson.
  - Kay.
  - Kingfisher.
  - Kiowa.
  - Logan.
  - McClain.
  - Major.
  - Mayes.
  - Noble.
  - Nowata.
  - Oklahoma.
  - Osage.
  - Ottawa.
  - Pawnee.
  - Rogers.
  - Stephens.
  - Texas.
  - Tillman.
  - Tulsa.
  - Wagoner.
  - Washington.
  - Woods.
  - Woodward.
- 65 to 69 cents—
  - Carter.
  - Creek.
  - Haskell.
  - Hughes.
  - Jefferson.
  - Lincoln.
  - McIntosh.
  - Murray.
  - Muskogee.
  - Okfuskee.
  - Okmulgee.
  - Payne.
  - Pontotoc.
  - Pottawatomie.
  - Seminole.
  - Sequoyah.
- 70 to 74 cents—
  - Atoka.
  - Bryan.
  - Choctaw.
  - Coal.
  - Johnston.
  - Latimer.
  - LeFlore.
  - Love.
  - Marshall.
  - Pittsburg.
- 75 to 79 cents—
  - McCurtain.
  - Pushmataha.

Oregon:
- 70 to 74 cents—
  - Clackamas.
  - Marion.
- 75 to 79 cents—
  - Douglas.
  - Jackson.

- Oregon—Continued.
  - 75 to 79 cents—
    - Lane.
    - Linn.
- Pennsylvania:
  - 65 to 69 cents—
    - Adams.
    - Berks.
    - Center.
    - Chester.
    - Clinton.
    - Columbia.
    - Crawford.
    - Cumberland.
    - Dauphin.
    - Erie.
    - Franklin.
    - Juniata.
    - Lancaster.
    - Lawrence.
    - Lebanon.
    - Lycoming.
    - Mercer.
    - Mifflin.
    - Montour.
    - Northumberland.
    - Perry.
    - Snyder.
    - Union.
    - Warren.
    - York.
  - 70 to 74 cents—
    - Armstrong.
    - Beaver.
    - Bedford.
    - Blair.
    - Bradford.
    - Bucks.
    - Butler.
    - Clarion.
    - Delaware.
    - Elk.
    - Fulton.
    - Huntingdon.
    - Indiana.
    - Jefferson.
    - Lehigh.
    - McKean.
    - Montgomery.
    - Northampton.
    - Philadelphia.
    - Potter.
    - Somerset.
    - Susquehanna.
    - Tioga.
    - Venango.
    - Westmoreland.
  - 75 to 79 cents—
    - Allegheny.
    - Cambria.
    - Cameron.
    - Carbon.
    - Clearfield.
    - Fayette.
    - Greene.
    - Lackawanna.
    - Luzerne.
    - Monroe.
    - Pike.
    - Schuylkill.
    - Sullivan.
    - Washington.
    - Wayne.
    - Wyoming.
- Rhode Island:
  - 85 to 89 cents—
    - Briston.
    - Kent.
    - Newport.
    - Providence.
  - $1 and over—
    - Washington.
- South Carolina:
  - 85 to 89 cents—
    - Calhoun.
    - Charleston.
    - Colleton.
    - Dorchester.
    - Greenville.
- South Dakota—Con.
  - 85 to 89 cents—
    - Lexington.
    - Oconee.
    - Orangeburg.
    - Pickens.
    - Richland.
    - Spartanburg.
  - 90 to 94 cents—
    - Abbeville.
    - Aiken.
    - Anderson.
    - Bamberg.
    - Barnwell.
    - Beaufort.
    - Berkeley.
    - Cherokee.
    - Chester.
    - Clarendon.
    - Edgefield.
    - Fairfield.
    - Greenwood.
    - Hampton.
    - Jasper.
    - Kershaw.
    - Lancaster.
    - Laurens.
    - Lee.
    - Newberry.
    - Saluda.
    - Sumter.
    - Union.
    - York.
  - 95 to 99 cents—
    - Chesterfield.
    - Darlington.
    - Dillon.
    - Florence.
    - Georgetown.
    - Horry.
    - Marion.
    - Marlboro.
    - Williamsburg.
- South Dakota:
  - 45 to 49 cents—
    - Aurora.
    - Beadle.
    - Bon Homme.
    - Brookings.
    - Brule.
    - Charles Mix.
    - Clay.
    - Davison.
    - Deuel.
    - Douglas.
    - Grant.
    - Gregory.
    - Hanson.
    - Hutchinson.
    - Jerauld.
    - Kingsbury.
    - Lake.
    - Lincoln.
    - McCook.
    - Miner.
    - Minnehaha.
    - Moody.
    - Sanborn.
    - Tripp.
    - Turner.
    - Union.
    - Yankton.
  - 50 to 54 cents—
    - Brown.
    - Buffalo.
    - Clark.
    - Codington.
    - Day.
    - Hamlin.
    - Hand.
    - Hyde.
    - Lyman.
    - Marshall.
    - Roberts.
    - Spink.
  - 55 to 59 cents—
    - Campbell.
    - Edmunds.
    - Faulk.
- South Dakota—Contd.
  - 55 to 59 cents—
    - Hughes.
    - McPherson.
    - Potter.
    - Sully.
    - Walworth.
  - 65 to 69 cents—
    - Butte.
    - Custer.
    - Fall River.
    - Harding.
    - Lawrence.
    - Meade.
    - Pennington.
    - Perkins.
- Tennessee:
  - 55 to 59 cents—
    - Dyer.
    - Lake.
    - Obion.
  - 60 to 64 cents—
    - Bedford.
    - Cannon.
    - Coffee.
    - Crockett.
    - Decatur.
    - Dekalb.
    - Franklin.
    - Gibson.
    - Giles.
    - Hardin.
    - Henry.
    - Hickman.
    - Humphreys.
    - Lauderdale.
    - Lincoln.
    - Marshall.
    - Maury.
    - Montgomery.
    - Moore.
    - Perry.
    - Rutherford.
    - Stewart.
    - Warren.
    - Weakley.
    - Williamson.
  - 65 to 69 cents—
    - Benton.
    - Bledsoe.
    - Carroll.
    - Cheatham.
    - Chester.
    - Clay.
    - Davidson.
    - Dickson.
    - Greene.
    - Grundy.
    - Hamblen.
    - Hancock.
    - Hawkins.
    - Haywood.
    - Henderson.
    - Houston.
    - Jackson.
    - Jefferson.
    - Lawrence.
    - Lewis.
    - McNairy.
    - Macon.
    - Madison.
    - Marion.
    - Overton.
    - Pickett.
    - Putnam.
    - Robertson.
    - Sequatchie.
    - Smith.
    - Sumner.
    - Tipton.
    - Trousdale.
    - Van Buren.
    - Wayne.
    - White.
    - Wilson.
  - 70 to 74 cents—
    - Anderson.
    - Blount.
    - Bradley.
- Tennessee—Contd.
  - 70 to 74 cents—
    - Campbell.
    - Claiborne.
    - Cocke.
    - Cumberland.
    - Fayette.
    - Fentress.
    - Grainger.
    - Hamilton.
    - Hardeman.
    - James.
    - Knox.
    - Loudon.
    - McMinn.
    - Meigs.
    - Monroe.
    - Morgan.
    - Polk.
    - Rhea.
    - Roane.
    - Scott.
    - Sevier.
    - Shelby.
    - Sullivan.
    - Union.
    - Washington.
  - 75 to 79 cents—
    - Carter.
    - Johnson.
    - Unicoi.
- Texas:
  - 55 to 59 cents—
    - Gray.
    - Hemphill.
    - Lipscomb.
    - Roberts.
    - Wheeler.
  - 60 to 64 cents—
    - Armstrong.
    - Briscoe.
    - Childress.
    - Collingsworth.
    - Donley.
    - Hale.
    - Hall.
    - Swisher.
  - 65 to 69 cents—
    - Cottle.
    - Crosby.
    - Floyd.
    - Foard.
    - Hardeman.
    - Motley.
    - Wichita.
    - Wilbarger.
  - 70 to 74 cents—
    - Archer.
    - Atascosa.
    - Bandera.
    - Bastrop.
    - Baylor.
    - Bell.
    - Bexar.
    - Blanco.
    - Burnet.
    - Caldwell.
    - Clay.
    - Collin.
    - Colorado.
    - Comal.
    - Cooke.
    - Coryell.
    - Delta.
    - Denton.
    - De Witt.
    - Dickens.
    - Falls.
    - Fannin.
    - Fayette.
    - Gillespie.
    - Gonzales.
    - Grayson.
    - Guadalupe.
    - Hamilton.
    - Hays.
    - Hopkins.
    - Hunt.
    - Karnes.

- Texas—Continued.
  - 70 to 74 cents—
    - Kendall.
    - Kerr.
    - King.
    - Knox.
    - Lamar.
    - Lampasas.
    - Lavaca.
    - Medina.
    - Milam.
    - Montague.
    - Travis.
    - Williamson.
    - Wilson.
  - 75 to 79 cents—
    - Aransas.
    - Austin.
    - Bee.
    - Bosque.
    - Bowie.
    - Brazoria.
    - Brazos.
    - Brown.
    - Burleson.
    - Calhoun.
    - Callahan.
    - Camp.
    - Cass.
    - Chambers.
    - Comanche.
    - Dallas.
    - Eastland.
    - Ellis.
    - Erath.
    - Fort Bend.
    - Franklin.
    - Freestone.
    - Galveston.
    - Goliad.
    - Gregg.
    - Grimes.
    - Harris.
    - Harrison.
    - Haskell.
    - Hill.
    - Hood.
    - Jack.
    - Jackson.
    - Jim Wells.
    - Johnson.
    - Kaufman.
    - Kimble.
    - Kleberg.
    - Lee.
    - Leon.
    - Liberty.
    - Limestone.
    - Live Oak.
    - Llano.
    - McLennan.
    - Madison.
    - Marion.
    - Mason.
    - Matagorda.
    - Mills.
    - Montgomery.
    - Morris.
    - Navarro.
    - Nueces.
    - Palo Pinto.
    - Panola.
    - Parker.
    - Rains.
    - Red River.
    - Refugio.
    - Robertson.
    - Rockwall.
    - Rusk.
    - San Patricio.
    - San Saba.
    - Shackelford.
    - Somervell.
    - Stephens.
    - Stonewall.
    - Tarrant.
    - Throckmorton.
    - Titus.
    - Upshur
- Texas—Continued.
  - 75 to 79 cents—
    - Van Zandt.
    - Victoria.
    - Waller.
    - Washington.
    - Wharton.
    - Wise.
    - Wood.
    - Young.
  - 80 to 84 cents—
    - Anderson.
    - Angelina.
    - Borden.
    - Cherokee.
    - Coke.
    - Coleman.
    - Concho.
    - Fisher.
    - Hardin.
    - Henderson.
    - Houston.
    - Howard.
    - Jasper.
    - Jefferson.
    - Jones.
    - McCulloch.
    - Menard.
    - Mitchell.
    - Nacogdoches.
    - Newton.
    - Nolan.
    - Orange.
    - Polk.
    - Runnels.
    - Sabine.
    - San Augustine.
    - San Jacinto.
    - Scurry.
    - Shelby.
    - Smith.
    - Taylor.
    - Tom Green.
    - Trinity.
    - Tyler.
    - Walker.
- Vermont:
  - 75 to 79 cents—
    - Addison.
    - Caledonia.
    - Chittenden.
    - Essex.
    - Franklin.
    - Grand Isle.
    - Lamoille.
    - Orange.
    - Orleans.
    - Windsor.
  - 80 to 84 cents—
    - Bennington.
    - Rutland.
    - Washington.
    - Windham.
- Virginia:
  - 60 to 64 cents—
    - Accomac.
    - Northampton.
  - 65 to 69 cents—
    - Clarke.
    - Fauquier.
    - Frederick.
    - Loudoun.
  - 70 to 74 cents—
    - Albemarle.
    - Alexandria.
    - Augusta.
    - Bedford.
    - Botetourt.
    - Caroline.
    - Culpeper.
    - Essex.
    - Fairfax.
    - Gloucester.
    - Greene.
    - King and Queen.
    - King George.
    - King William.
    - Lancaster.
    - Lee.
- Virginia—Continued.
  - 70 to 74 cents—
    - Madison.
    - Mathews.
    - Middlesex.
    - Northumberland.
    - Orange.
    - Page.
    - Prince William.
    - Rappahannock.
    - Richmond.
    - Rockbridge.
    - Rockingham.
    - Scott.
    - Shenandoah.
    - Spotsylvania.
    - Stafford.
    - Warren.
    - Westmoreland.
  - 75 to 79 cents—
    - Amelia.
    - Amherst.
    - Appomattox.
    - Buckingham.
    - Campbell.
    - Charles City.
    - Chesterfield.
    - Cumberland.
    - Elizabeth City.
    - Fluvanna.
    - Goochland.
    - Hanover.
    - Henrico.
    - James City.
    - Louisa.
    - Nansemond.
    - Nelson.
    - New Kent.
    - Norfolk.
    - Powhatan.
    - Prince Edward.
    - Princess Anne.
    - Warwick.
    - York.
  - 80 to 84 cents—
    - Alleghany.
    - Bath.
    - Brunswick.
    - Charlotte.
    - Craig.
    - Dinwiddie.
    - Floyd.
    - Franklin.
    - Giles.
    - Greenesville.
    - Halifax.
    - Henry.
    - Highland.
    - Isle of Wight.
    - Lunenburg.
    - Mecklenburg.
    - Montgomery.
    - Nottoway.
    - Pittsylvania.
    - Prince George.
    - Pulaski.
    - Roanoke.
    - Smyth.
    - Southampton.
    - Surry.
    - Sussex.
    - Washington.
    - Wythe.
  - 85 to 89 cents—
    - Bland.
    - Buchanan.
    - Carroll.
    - Dickenson.
    - Grayson.
    - Patrick.
    - Russell.
    - Tazewell.
    - Wise.
- Washington:
  - 70 to 74 cents—
    - Asotin.
    - Columbia.
    - Ferry.
    - Garfield.
    - Lincoln.
- Washington—Contd.
  - 70 to 74 cents—
    - Stevens.
    - Walla Walla.
    - Whitman.
  - 75 to 79 cents—
    - Adams.
    - Chelan.
    - Douglas.
    - Grant.
    - Okanogan.
    - Spokane.
    - Yakima.
- West Virginia:
  - 65 to 69 cents—
    - Berkeley.
    - Cabell.
    - Jefferson.
    - Mason.
    - Wayne.
  - 70 to 74 cents—
    - Brooke.
    - Hancock.
    - Jackson.
    - Marshall.
    - Ohio.
    - Pleasants.
    - Tyler.
    - Wetzel.
    - Wood.
  - 75 to 79 cents—
    - Calhoun.
    - Grant.
    - Hampshire.
    - Hardy.
    - Kanawha.
    - Lincoln.
    - Logan.
    - Mineral.
    - Mingo.
    - Morgan.
    - Putnam.
    - Ritchie.
    - Roane.
    - Wirt.
  - 80 to 84 cents—
    - Barbour.
    - Boone.
    - Braxton.
    - Clay.
    - Doddridge.
    - Fayette.
    - Gilmer.
    - Greenbrier.
    - Harrison.
    - Lewis.
    - McDowell.
    - Marion.
    - Mercer.
    - Monongalia.
    - Monroe.
    - Nicholas.
    - Pendleton.
    - Pocahontas.
    - Preston.
    - Raleigh.
    - Randolph.
    - Summers.
    - Taylor.
    - Tucker.
    - Upshur.
    - Webster.
    - Wyoming.
- Wisconsin:
  - 50 to 54 cents—
    - Buffalo.
    - Eau Claire.
    - Pepin.
    - Pierce.
    - Trempealeau.
  - 55 to 59 cents—
    - Adams.
    - Burnett.
    - Chippewa.
    - Columbia.
    - Crawford.
    - Dane.
    - Dunn.
    - Grant.
    - Green.

Wisconsin—Contd.
- 55 to 59 cents—
  - Green Lake.
  - Iowa.
  - Jackson.
  - Juneau.
  - La Crosse.
  - Lafayette.
  - Marquette.
  - Monroe.
  - Polk.
  - Richland.
  - Rock.
  - Rusk.
  - St. Croix.

Wisconsin—Contd.
- 55 to 59 cents—
  - Sauk.
  - Vernon.
  - Walworth.
- 60 to 64 cents—
  - Barron.
  - Clark.
  - Dodge.
  - Fond du Lac.
  - Jefferson.
  - Kenosha.
  - Milwaukee.
  - Outagamie.
  - Ozaukee.

Wisconsin—Contd.
- 60 to 64 Cents—
  - Portage.
  - Racine.
  - Shawano.
  - Sheboygan.
  - Washburn.
  - Washington.
  - Waukesha.
  - Waupaca.
  - Waushara.
  - Winnebago.
  - Wood.
- 65 to 69 cents—
  - Brown.

Wisconsin—Contd.
- 65 to 69 cents—
  - Calumet.
  - Door.
  - Kewaunee.
  - Manitowoc.
  - Marinette.
  - Oconto.
- 70 to 74 cents—
  - Langdale.
  - Marathon.

Wyoming:
- 70 to 74 cents—
  - Crook.
  - Laramie.

UNITED STATES DEPARTMENT OF AGRICULTURE

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WM. A. TAYLOR, Chief

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CITRUS-FRUIT IMPROVEMENT: A STUDY OF BUD VARIATION IN THE MARSH GRAPEFRUIT.[1]

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INTRODUCTION.

The commercial production of grapefruit (*Citrus grandis* Osbeck) in California began about 1890. Previous to this time, bearing grapefruit trees of many varieties were to be found in some citrus orchards, but the crops from these trees were largely used for home consumption or were sold in local markets. Most of the early plantings were of Florida-grown trees and of varieties many of which proved to be undesirable for California conditions. The fruits usually contained a large number of seeds and were inferior in size, shape, texture, flavor, or other important commercial characteristics.

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[1] This is the third in a series of publications summarizing the citrus fruit-improvement investigations of the United States Department of Agriculture. The two previous reports were presented in Department Bulletins Nos. 623 and 624, treating of the work with the Washington Navel orange and the Valencia orange, respectively.

Consequently, the reputation of California grapefruit in many important markets was below that of fruit from other grapefruit-growing regions, and the culture of this fruit in the State was found to be unprofitable in most instances.

One of the varieties introduced into California from Florida about 1890 was later known as the Marsh, or, as it has been more commonly called, the Marsh Seedless. The trees of this variety were found to produce superior fruits, particularly from the standpoint of commercial quality, including the characteristics of a flattened, desirable shape, smooth texture and fine color of rind, few or no seeds, abundance of juice, tender and palatable rag, and a highly developed grapefruit flavor.

The former lack of commercial success of the California grapefruit industry, due to the planting of varieties not suitable for California conditions, discouraged extensive plantings of this fruit for many years. The success of the Marsh variety, not only in western but in some eastern markets as well, has led to a recent reawakening of interest in the production of this fruit in California and to extensive commercial plantings in several districts. The fruits of the Marsh variety ripen during the late spring and summer months in California. The Florida grapefruit crop is largely marketed during the late fall, winter, and early spring months, so that the California-grown Marsh grapefruit crop can be sold in eastern markets at a time when it does not compete with the Florida crop or the crops of other important grapefruit-growing regions. In addition to the eastern, there are several important California markets which must be supplied with California-grown grapefruit on account of a rigid quarantine against all grapefruit from other districts. This quarantine has been established by reason of the danger of the introduction of serious citrus pests and diseases into the orchards of that State.

The Thirteenth Census gives the production of California grapefruit in 1909 as 122,515 boxes. The production of other important California citrus fruits that year was 14,436,180 boxes of oranges, 2,756,221 boxes of lemons, 3,581 boxes of tangerines, and 555 boxes of mandarins.

The plantings of grapefruit trees in California in 1910 were shown by the Thirteenth Census to total 43,424 bearing trees. Figured at the rate of 90 trees to the acre, these trees were planted on about 482 acres. At the same time it was found that there were 25,589 trees not in bearing, which, at the rate of planting mentioned above, would amount to 284 acres of nonbearing trees.

The plantings in 1915, as shown by figures compiled by the California Fruit Growers' Exchange,[1] consisted of 56,224 trees, or about 625 acres in bearing, and 203,580 trees, or about 2,262 acres, not in bearing. The past season several additional large plantings of the Marsh variety have been made, particularly in the Imperial and Coachella Valleys in southern California, and many smaller plantings have been made in other citrus districts of the State.

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[1] Letter from F. O. Wallschlaeger, Los Angeles, Cal., June 7, 1916.

While the grapefruit crop of California at present is of relatively small commercial importance as compared with the orange or lemon crops, it seems likely that in the next few years it will become a more important factor in the citrus industry of the State. Many of the growers, with this viewpoint, have organized the California Grapefruit Club, for the special purpose of cooperating in extending the market for this fruit, in order to take care of the greatly enlarged production now in prospect. One of the most important means for increasing the consumption of this fruit is through the improvement of the crop by discarding all inferior varieties, standardizing the Marsh variety by the elimination of all trees of inferior and poor strains,[1] and the growing of only the best strain, propagated from the most productive and valuable trees, selected on the basis of their performance records.

The California Grapefruit Club took official action to this end during the season of 1916. It began a tree-census record of all of the grapefruit orchards belonging to the members of the club, securing accurate data upon the number of trees of each variety and each strain in every orchard. The members of the club agreed to top-work the trees of all varieties other than the Marsh, and the trees of all strains other than the Marsh,[2] or most desirable, strain. The top-worked trees for the most part have been rebudded with buds secured from superior select trees of the Marsh strain, or, in a few cases, with buds from trees of other varieties of citrus fruits. Most of this work has already been accomplished, and it was expected that it would be completed during the season of 1917.

In March, 1917, the California Fruit Growers' Exchange, through its field department, undertook similar work for its members with the standard orange and lemon varieties. Individual-tree performance records are being kept in several very productive groves, for the purpose of locating desirable trees as reliable sources of bud wood for use in top-working or for the propagation of young trees. This action was taken because the commercial nurserymen were able to supply only a very small part of the bud wood or nursery trees of this character demanded by the citrus growers.

These actions are interesting examples of the utilization of the results of scientific research in agriculture by large commercial organizations.

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[1] The term "strain" is here used to designate a group of individuals of a horticultural variety which differ from all other individuals of the variety in one or more constant and recognizable characteristics capable of perpetuation through vegetative propagation.

[2] The name Marsh has been applied to the best strain of the variety, because, as nearly as can be determined, it is similar in character of tree and fruit to the original Marsh introduction.

HISTORY OF THE VARIETY.

The Marsh variety of grapefruit was introduced by Mr. C. M. Marsh, at Lakeland, Fla.[1] The original tree was one of a grove of large seedling grapefruit trees near the city of Lakeland owned by Mr. Marsh.

In 1895 this tree was killed to the ground during the freeze of that year, at which time it was 50 or 60 years old. Previous to the freeze, Mr. Marsh had begun to propagate from this tree, on account of the superior qualities of its fruits, which were commercially seedless,[2] usually producing only three to five seeds. At the time of the freeze he had some 50,000 or 60,000 nursery trees budded from the parent tree and its progeny, but these trees were killed by the freeze. Fortunately, before the freeze, Mr. Marsh had collected and stored in his packing house about 70,000 buds for spring budding. After the freeze, all available stocks were budded with these stored buds, and from this propagation about 10,000 young trees were secured. The distribution of these trees and buds cut from them marked the introduction of this variety in Florida. It was about this time that the name Marsh Seedless was given to the variety by the originator. Later, the American Pomological Society adopted the name Marsh, instead of Marsh Seedless, for this variety.

The first introduction of the Marsh variety into California was probably accomplished by the nursery firm of Twogood & Cutter, at Riverside. In a letter [3] from J. E. Cutter the following account of this introduction is given:

> In 1890, Dr. N. A. Claflin, later horticultural commissioner of Riverside County, went to Florida as agent to ship stock for the nursery trade of Twogood & Cutter. Returning, he brought a small bundle of seedless grapefruit trees, obtained at Lakeland or vicinity. He did not report the name "Marsh Seedless," but the Marsh is understood to have originated at that place, and there can be no reasonable doubt that they were such. I do not know of any other strain. One of these trees was planted by myself in my (present) home grounds, where it still stands. So far as I know and believe, it was the first "seedless" to bear fruit in this State, but doubtless others also obtained the variety from Florida.

The tree planted by Mr. Cutter in his home grounds is shown in Plate I. It is the true Marsh variety beyond question.

Many of the Marsh grapefruit orchards in California were planted with trees which were propagated by Twogood & Cutter or other California nurserymen from the Claflin introduction. A few orchards were planted with Florida-grown trees or from later introductions of Marsh bud wood from Florida.

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[1] Personal statement of Mr. Marsh, Jacksonville, Fla., May, 1916.

[2] The presence of not over 12 seeds per fruit is considered by the California Grapefruit Club as permissible in fruits designated as commercially seedless.

[3] Letter from Mr. Cutter, Riverside, Cal., June 13, 1916.

Hume states[1] that under Florida conditions, the fruit of the Marsh variety "has not the distinct, pronounced flavor of the typical fruit, but the quality is good, and the fact that it is so nearly seedless is a very desirable feature." The effect of climatic and, perhaps, other conditions in California has been such as to produce in the fruits of this variety the highly developed grapefruit flavor desired.

A similar illustration of the effect of climatic and other conditions on the quality of citrus fruits is found in the behavior of the Washington Navel orange. In the tropical region at Bahia, Brazil, these oranges lack the highly developed flavor which the fruits of this variety possess when grown in California.

In California the trees of the Marsh grapefruit normally bloom in March, and the fruits from this bloom ripen from May to September of the following year. Owing to this condition, the trees frequently support two crops, both young and nearly mature fruits, at the same time during the spring and summer months.

The trees of this variety in California are usually more productive than the trees of the Valencia or Washington Navel orange varieties under the conditions of soil and climate best suited to the development of the finest quality of grapefruit; i. e., a fertile, coarse or sandy loam soil, and the same climatic conditions which are most favorable for the production of the highest flavor and quality in the Washington Navel orange.

VARIABILITY WITHIN THE VARIETY.

Bud variation in trees of the Marsh variety of grapefruit occurs with about the same degree of frequency as is the case with the Washington Navel orange and other varieties of citrus fruits which have been studied in the course of the investigations for the improvement of citrus fruits through bud selection. The variation of the fruits is of the most importance from the commercial standpoint, and for this reason this phase of the problem has been given most study. Variations of the habit of growth of the trees, foliage, and flower characteristics are probably of as frequent occurrence as those of fruit variations, but on account of the smaller commercial importance of these characteristics they have been given comparatively little attention up to the present time in these investigations. No doubt there are well-defined correlations of fruit, foliage, and flower characters, and when these correlations have been fully worked out they may be of importance in determining the character of the trees and their value for fruit production.

One of the most valuable groves of the Marsh variety of grapefruit in California at the present time was planted near Riverside in 1898. A preliminary individual-tree census study of this grove made by the senior writer in 1909 revealed the fact that there existed in the grove a striking diversity in the characteristics of the trees. Out of a total of about 500 trees, 123, or nearly 25 per cent, produced fruits having from 30 to 90 seeds in each fruit. The trees bearing these very seedy fruits were found to have a characteristic drooping habit of growth, from which it soon became possible to identify them wherever they occurred in the grove. The fruit from this grove had been guaranteed by the owner to be commercially seedless, and the occurrence of the seedy fruits in the crops, when noticed by the buyers, led to a considerable depreciation in their value on the markets. Upon the discovery that the seedy fruits were borne only by trees of a certain character, these fruits were eliminated, except those occurring as individual fruit and limb variations, by top-working the trees which produced them, using for this purpose buds selected from trees of the true Marsh strain, which is commercially seedless. One of the trees of the Marsh strain in this grove is shown in Plate II and one of the trees of the Rough Seedy strain in Plate III.

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[1] Hume, H. H. Citrus Fruits and Their Culture, ed. 5, p. 120. New York, 1913.

An interesting characteristic of the production from individual trees was revealed by the tree-census studies in the Marsh grove first studied. Some of the trees bore very heavy crops, while others, very similar in general appearance to the productive trees, bore only a few fruits. Further observation of this condition during the following years revealed the fact that some of the trees possessed the habit of bearing heavy crops one season and light ones the next. The trees having this habit have been called alternate bearers, from the fact that they usually bear full crops only every other year.

Another strain of trees was found in this grove bearing fruits having a modified pyriform, or bell-like, shape in contrast with the flattened, or oblate, shape of typical fruits of the Marsh strain. These trees have been called the Bell strain on account of the shape of their fruits. This shape, from the market standpoint, is not so desirable as the flattened one of the Marsh strain, and the fruits are likely to be later in ripening than those of other strains.

The fruits borne by the trees of the Marsh strain have a comparatively thin rind of very smooth texture and waxy-white appearance. Some of the trees in the performance-record plat were found to produce fruits having very thick rinds with a rough or coarse texture and yellowish color. The fruits of this Rough strain, as a rule, have a shape more nearly round or globular than those of the Marsh strain, while the flesh, juice, and other characteristics are somewhat similar to those of that strain.

Individual-tree census observations made in other groves located in various citrus districts of southern California have brought out clearly the fact that the trees in these orchards vary in about the same manner as those in the grove described above. More than 25 per cent of the trees in the bearing orchards under observation are of strains that are inferior to the Marsh or best strain.

Among the variable fruits occurring in trees of the Marsh strain are those of the Corrugated, Seedy, Bell, and Rough strains, those having raised or sunken sections or both, navel fruits, and those showing parts typical of two or more of the strains. Fruits of the Corrugated strain are usually large, pyriform in shape, with thick, deeply creased rinds, and they are generally of inferior flavor and have little juice. Fruits of the Seedy strain are frequently very similar in appearance and other characteristics to fruits of the Marsh strain except that instead of a few or no seeds, they contain from 25 to 100 seeds each. Fruits of the Bell strain frequently have smooth rinds, and those of the Rough strain have the white color of the fruits of the Marsh strain. These fruit variations have been found to occur in trees of the Marsh strain either as single fruits or as limbs bearing several fruits.

In addition to the fruit variations listed above, absolutely seedless fruits and limbs bearing seedless fruits have been found in trees of the Marsh strain. In the studies made up to the present time, no instances have been found in which all of the fruits on a tree were absolutely seedless.

Fruits setting out of the normal blooming period often have pyriform or irregular shapes, which are undesirable from the market standpoint. These fruits usually have very thick rinds, a coarse and bitter rag, and lack the distinctive grapefruit flavor of the normal fruits borne by the same trees. No logical reason has been presented to account for the characteristics of these peculiar so-called ''off-bloom'' fruits. Some trees bear more of them than others under apparently similar conditions.

All of the strains of grapefruit described in this bulletin have been found as individual fruit or limb variations in trees of the Marsh strain. Fruits of the Marsh and other strains have been found occurring as single fruit or limb variations in trees of the Seedy, Alternate-Bearing, Bell, and Rough strains.

Many minor variations in grapefruits have been found in the course of these investigations. Their significance is not fully understood as yet, and for this reason no discussion of these variations will be offered at this time.

The presence in established orchards of trees of the several strains discovered in the performance-record plats shows the importance of this work. These various strains of the Marsh grapefruit have originated in all probability from bud variations, and there is little doubt that the diversity in the trees in existing grapefruit orchards is the result of the unintentional propagation of bud variations due to the prevailing haphazard methods of gathering bud wood. The commercial inferiority of the product from such trees constitutes one of the important reasons for the systematic selection of bud wood from trees of the right character.

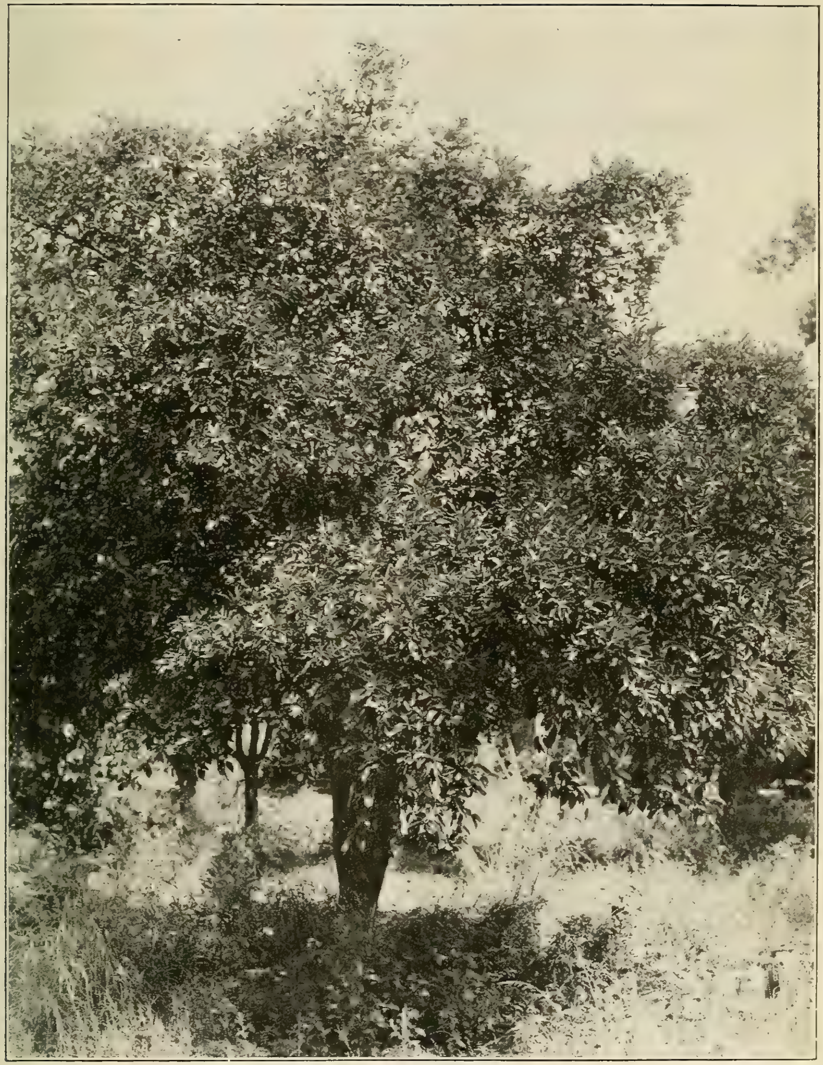
The diversity of strains of the Marsh variety represented in established groves is of great commercial importance to the grapefruit industry, for the reputation and value of the crop depends on the maintenance of a uniform quality. For this reason, the identification of the Marsh strain, which is the most productive and valuable strain of the variety, and the maintenance of the purity of the strain by bud selection are of fundamental importance in the development of the industry. This does not entail any increase in the cost of producing, handling, or distributing the crop. On the contrary, from the standpoint of cost of production based on the unit cost per box, the production of the best strains can be effected more cheaply than is the case when inferior and less productive strains are present.

Fruits containing many seeds, such as those of the Seedy strain, are of much less value than those which are commercially seedless. On account of the fact that some of the seedy fruits can not be readily separated after picking from those of the Marsh or other strains, the presence of trees of this strain in established groves is detrimental to the reputation and value of the crop as a whole.

The late-ripening characteristic of fruits of the Bell strain is also detrimental to the effort to build up a superior commercial reputation for this variety. The fruits of this strain are difficult to eliminate from the general pick and pack of the groves. Because of their unripe condition, if included with fruits of the Marsh strain they tend to detract from the quality of the whole package and to injure the reputation of the variety.

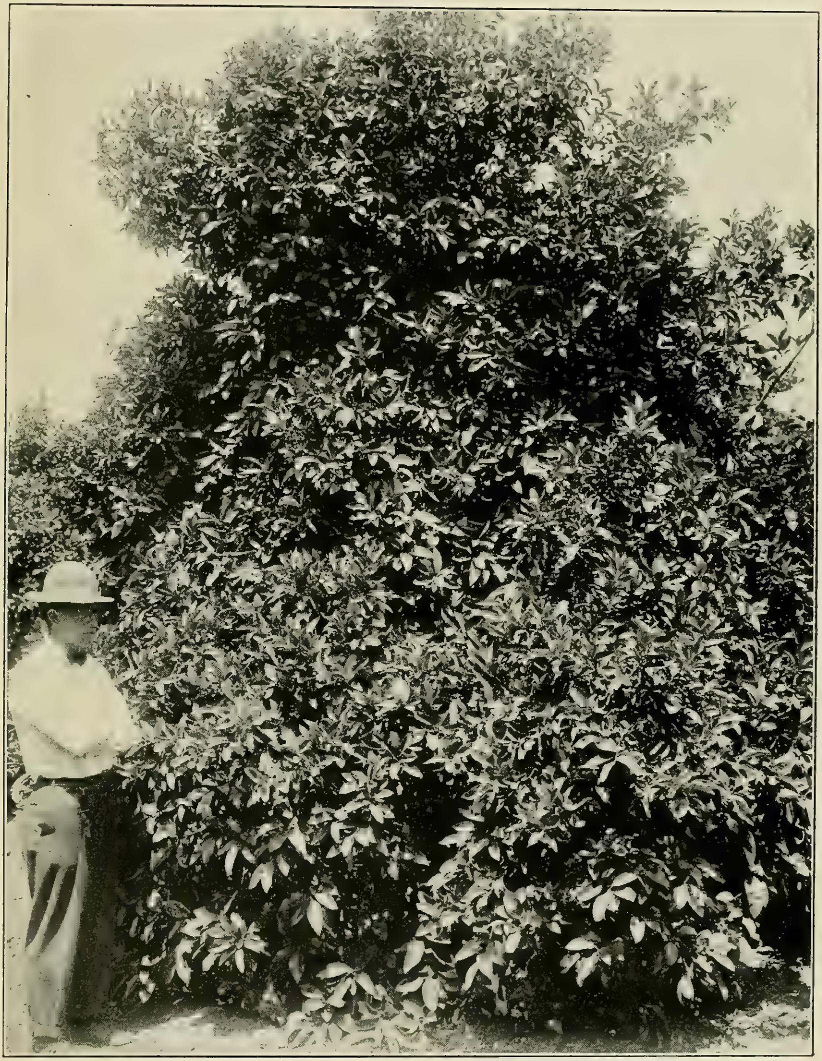
OBJECTS OF THE INVESTIGATIONS.

The objects of these investigations are (1) to determine the frequency of occurrence and the nature of bud variations in the Marsh variety of grapefruit, (2) to secure definite information concerning the commercial value of the different strains of this variety by means of individual-tree performance records, (3) to originate and introduce methods for isolating the best strains and controlling variation within them through bud selection based on tree-performance records and definite tree knowledge, (4) to eliminate the trees of inferior strains in established orchards by top-working them with select buds, and (5) to demonstrate the value and importance of the use of improved methods of propagation based on definite individual-tree knowledge for the improvement of the production of established orchards and for the conservation and improvement of the variety.



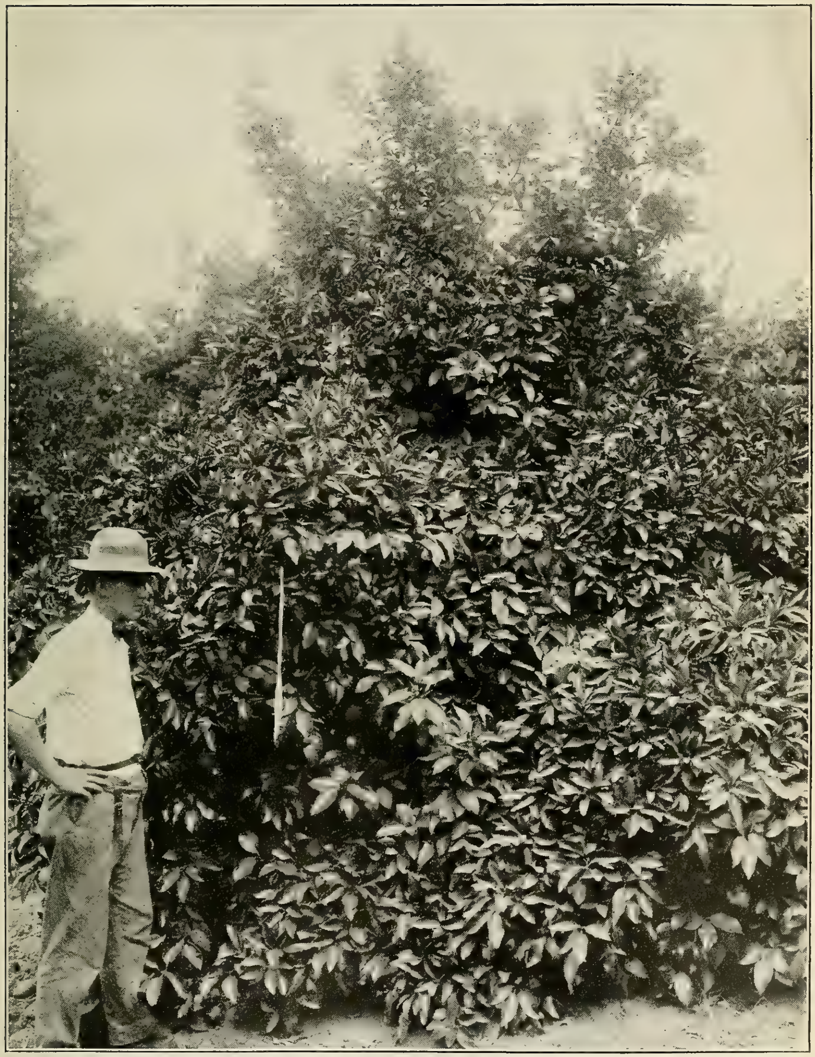
P935A—HP

THE FIRST MARSH GRAPEFRUIT TREE PLANTED IN CALIFORNIA, AT RIVERSIDE, ABOUT 1890, FROM WHICH MOST OF THE ORCHARDS IN CALIFORNIA HAVE BEEN PROPAGATED.



P900A—HP

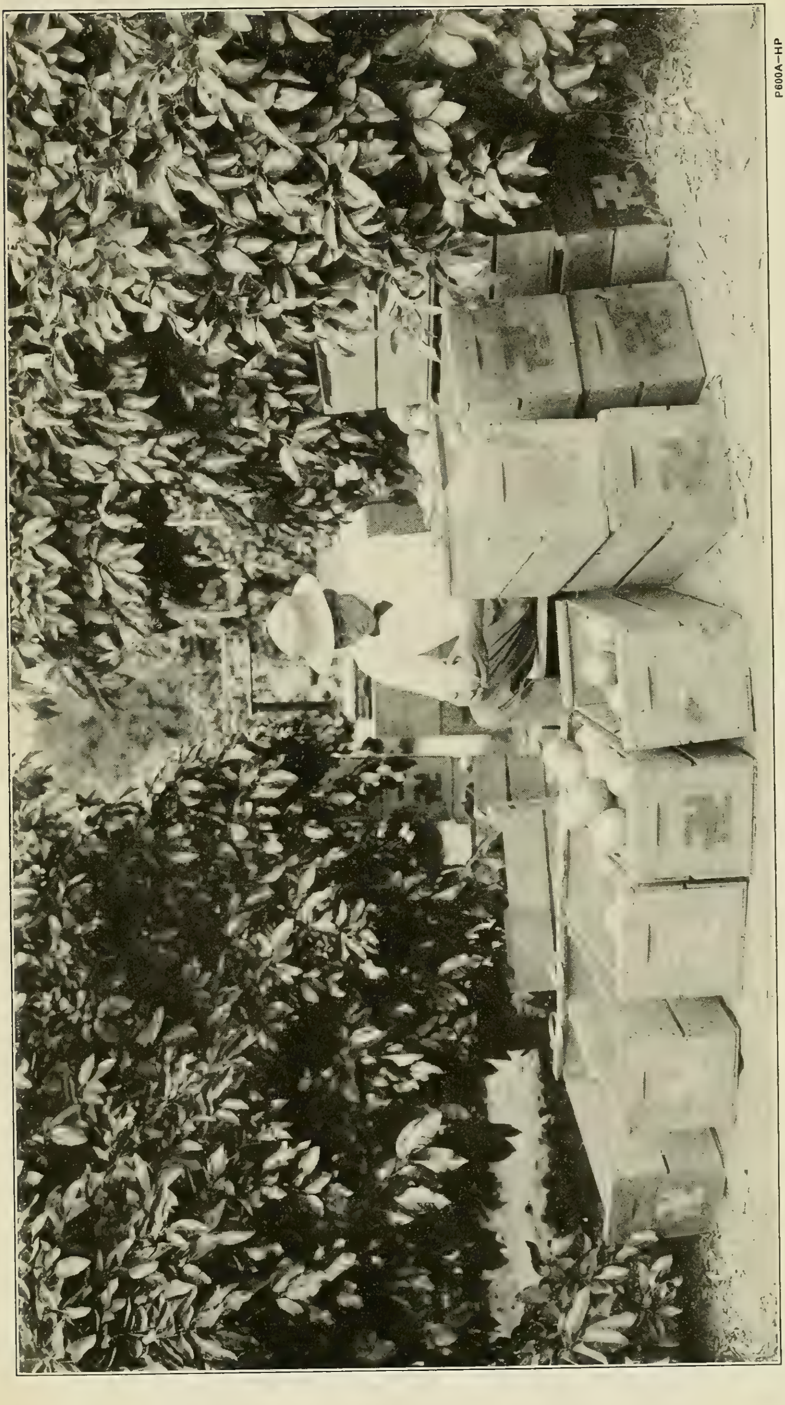
A TYPICAL TREE OF THE MARSH STRAIN OF THE MARSH GRAPEFRUIT, SHOWING ITS HABIT OF GROWTH AND FOLIAGE CHARACTERISTICS.



P915A—HP

A TYPICAL TREE OF THE ROUGH SEEDY STRAIN OF THE MARSH GRAPEFRUIT, SHOWING ITS PECULIAR DWARFED AND DROOPING HABIT OF GROWTH.

PLATE IV.



A MARSH GRAPEFRUIT PERFORMANCE-RECORD PLAT IN CALIFORNIA.

The arrangement of boxes for assorting the fruits according to size and the scales for weighing the same in making individual-tree performance records are here shown.

PLAN OF THE INVESTIGATIONS.

The selection of groves of Marsh grapefruit in which to conduct the work of these investigations was made by the senior writer in 1909, following a preliminary survey of the leading districts in which the grapefruit was then grown in California. The conditions considered most desirable in the preliminary study of these groves included (1) the successful and profitable production of fruit; (2) uniformity of soil and cultural conditions in the groves; (3) protection from tree injuries due to extreme climatic conditions, insect enemies, and fungous diseases; (4) definite knowledge of the source of buds and stocks from which the trees were grown; (5) plantings on virgin land; (6) reasonable assurance of several years of uninterrupted observations under the same orchard management; (7) the use of little or no manures or fertilizers and the absence of radical tree or cultural treatments; and (8) locations where the results of the investigations would be of the most service and value to the industry.

The performance-record plats finally selected for systematic observations were located in groves where the work of these investigations could be carried on with the least possible danger of interruption and where the conditions were as nearly as possible identical with those mentioned above. The trees studied in these investigations have all been grown on sweet-orange stocks, and the history of the buds used in their propagation is known.

In one performance-record plat, 25 trees were originally selected in one block for individual-tree study, and later another tree was added to this number. In the second performance-record plat, 52 trees in one block were originally selected for study, to which number 26 select trees have been added during subsequent seasons. Individual-tree records for six consecutive years have been obtained from the 25 trees in the first plat and from the 52 trees in the other plat. Most of the information presented in this bulletin was obtained from a study of the performance records of these 77 trees first selected for this work.

As a result of the performance-record work discussed in this bulletin, progeny tests of select trees and bud variations have been begun both by top-working bearing trees and with nursery stocks. Some of the results thus far obtained from these propagations will be discussed briefly at this time, but the complete description of such work will be left for publication in later reports.

METHODS OF KEEPING PERFORMANCE RECORDS.

The methods used in keeping the individual-tree performance records are fully described in Farmers' Bulletin 794 of the United States Department of Agriculture, entitled "Citrus-Fruit Improvement: How to Secure and Use Tree-Performance Records." In order to make the present discussion complete, the following brief résumé of the methods used for obtaining the grapefruit performance-record data is here given.

TREE NUMBERS.

The performance-record trees have been given individual-tree numbers, consisting of the number of the block, the number of the row, and the position of the tree in the row, counting always from some fixed point, as, for example, the irrigation head. This number is painted on the tree trunks, always in the same relative position, with white-lead paint. The figures are made large and plain and are so placed as to be easily legible and accessible.

PICKING.

The trees are picked by trained pickers from the regular crews employed on the properties where the plats are located. Usually the same men have picked the performance-record plats every season. In this work all of the fruits of each tree have been picked at one time. Owing to the fact that the eastern market season for California grapefruit is best in midsummer, a condition which has been recognized fully only recently by the California growers, the time of picking the performance-record plats has been postponed each year, until at the present time it begins during the latter part of June.

The fruits from the trees in the performance-record plats are, of necessity, handled more often than is ordinarily the case. For this reason, especial care has been used in handling, in order to avoid so far as possible all mechanical injuries to the fruits. After the performance-record observations have been completed, the crop of each tree, except such samples as may be required for further study, is included in the general field crop and sent to the packing house.

ASSORTING.

The fruits from the individual trees are assorted into three grades, viz, Ivory-White, Standard, and Cull. The Ivory-White or commercial grade corresponds to a first and the Standard to a second grade. The Ivory-White grade includes all of the most valuable commercial fruits; the Standard, all of the blemished fruits, or those having poor color, shape, or other inferior commercial characteristics, but suitable for shipment to market; and the Cull grade, those fruits which for any reason are not worthy of packing for the market.

The work of assorting grapefruits according to size and grade has, of necessity, been done by hand, as shown in Plate IV. No machines such as are used with other citrus fruits are available for sizing Marsh grapefruits satisfactorily for these investigations. In the performance-record work the fruits are first assorted into the usual commercial sizes, viz, 112 and smaller, 96, 80, 64, 48, 32, and 24 and larger, indicating the number of fruits per packed box. This work is done by the aid of rings, so that the assortment will be uniform for all trees. In commercial practice the sizing is largely done without the use of rings. After the fruits have been assorted according to size, each lot is assorted according to grade.

RECORDING.

The fruits of each grade of each size are counted and weighed, and the results entered on the performance-record blank, as shown in Table I, embodying the data from a productive tree of the Marsh strain of Marsh grapefruit in investigational plat A of the Dixon grove (planted in 1898), grown by L. V. W. Brown at Highgrove, Cal. At the time of entering the record one fruit of each grade of three sizes, viz, large, medium, and small, is laid aside for examination as to the number and characteristics of the seeds. Any variable or other unusual fruits are also taken out at this time for further detailed study and classification. The detailed performance record of each tree is copied from the field form on an annual form similar to that shown in the upper part of Tables I and II, and the summary record from the annual form is in turn entered on a period form, as shown in the lower part of Tables I and II.

TABLE I.—*Performance record of Marsh grapefruit tree No. 1–14–30, Productive Marsh strain.*[1] *showing the weight and number of fruits of each size and grade, seeds counted, and sports noted in detail for the season of 1912 and summarized for the 6-year period, 1910 to 1915, inclusive.*

[The summarized 6-year record illustrates the method of assembling the data of successive seasons for careful comparison and study. In practice, the variable fruits produced by the tree each season are listed on the back of the form. The weights are given in pounds and ounces, except that the 6-year totals and the averages are expressed decimally in pounds. This tree is listed in rank 1 of Table III.]

DETAILED RECORD FOR THE SEASON OF 1912.

Sizes of fruits.	Fruits.								Seeds.[2]	
	Ivory-White grade.		Standard grade.		Cull grade.		Total.		Ivory-White grade.	Standard grade.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
	Lbs. oz.		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
112 and smaller	48–13	74	69– 9	111			118– 6	185	1	3 0
96	36–10	49	28–10	37			65– 4	86		
80	56–14	71	42– 4	51			99– 2	122		
64	63– 5	71	27–15	31			91– 4	102	0	5 4
48	61– 7	63	24– 3	25			85–10	88		
32	37– 0	36	8– 7	8			45– 7	44		
24 and larger	65–12	55	11– 7	10			77– 3	65	0	0 1
Total	369–13	419	212– 7	273			582– 4	692	1	13
Grand total					8– 0	19	590– 4	711	14	

[1] NOTES.—Date: May 6, 1912. Fine large Marsh tree. Sports: Ridged, 2.
[2] Seeds of cull fruits not counted.

TABLE I.—*Performance record of Marsh grapefruit tree No. 1-14-30, etc.*—Continued.

SUMMARIZED RECORD FOR SIX SEASONS.

Grades and sizes.	1910	1911	1912	1913	1914	1915	Total.	Average.
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	
Ivory-White grade	187- 9	109- 9	369-13	149-12	240-12	292-11	1,350- 2	225.0
Standard grade	304- 7	532-11	212- 7	238- 7	218-12	192- 3	1,698-15	283.2
Cull grade	0- 0	0- 0	8- 0	72- 3	18- 0	21- 4	119- 7	29.9
Grand total	492- 0	642- 4	590- 4	460- 6	477- 8	506- 2	3,168- 8	528.1
Sizes—								
112 and smaller	47-15	394- 0	118- 6	241- 1	77- 8	152-13	1,031-11	171.9
96	18- 8	56- 9	65- 4	66- 9	83- 8	67- 2	357- 8	59.6
80	53-12	65-11	99- 2	36- 6	66-15	91- 6	413- 4	68.9
64	70- 9	56- 4	91- 4	17- 9	88- 5	70-15	394-14	65.8
48	61- 6	38- 6	85-10	10- 5	66- 1	44- 4	306- 0	51.0
32	66- 8	10-10	45- 7	5- 9	36-14	24- 6	189- 6	31.6
24 and larger	173- 6	20-12	77- 3	10-12	40- 5	34- 0	356- 6	59.4
Total	492- 0	642- 4	582- 4	388- 3	459- 8	484-14	3,049- 1	508.2
Number of fruits:								
Ivory-White grade	180	133	419	223	277	335	1,567	261
Standard grade	307	717	273	333	272	238	2,140	357
Cull grade[1]	0	0	19	193	54	36	302	76
Grand total	487	850	711	749	693	609	4,009	668
Sizes—								
112 and smaller	72	583	185	360	125	221	1,546	258
96	24	68	86	97	108	81	464	77
80	62	75	122	49	77	103	488	81
64	76	59	102	22	99	73	431	72
48	61	38	88	12	69	43	311	52
32	60	10	44	6	36	23	179	30
24 and larger	132	17	65	10	35	29	288	48
Total	487	850	692	556	549	573	3,707	618
Number of seeds:								
Ivory-White grade—								
112 and smaller	(2)	2	1	3	1	3	10	2.0
64	0	1	0	0	6	3	10	1.7
24 and larger	(2)	3	0	0	3	6	12	2.4
Standard grade—								
112 and smaller	(2)	(2) 1	3 0	2	2	3	8	1.6
64	0 0	3 4	5 4	2	4	2	16	2.7
24 and larger	(2)	4 2	0 1	0	3	6	12	2.4
Cull grade—								
112	(2)	(2)	(2)	(2)	3	5	11	3.7
64	(2)	(2)	(2)	(2)	1	4	13	2.6
24 and larger	(2)	(2)	(2)	(2)	2	8	14	3.5
Total	0	20	14	7	25	40	106	2.4

[1] The excessive number of culls occurring in 1913 were due to the severe freeze of that season.
[2] Not counted.

Descriptions of the important strains and variations from these strains are made in the field. Photographs of typical trees and fruits and their variations are obtained during the performance-record work, in order to illustrate their characteristics. All of the information collected in this way is brought together at the end of the season and classified.

DESCRIPTIONS OF IMPORTANT STRAINS.

The following descriptions of some of the important strains of the Marsh variety of grapefruit are summarized from detailed field observations, measurements, and studies of typical trees and fruits.

They are presented for the purpose of illustrating the most important characteristics of the strains and to furnish a basis for understanding and interpreting more fully than otherwise would be possible the tables and discussions of the behavior and value of the trees of these strains.

MARSH STRAIN.

The trees of the Marsh strain, an example of which is shown in Plate II, are the most productive and bear larger crops of desirable and valuable fruits than any of the other strains of the Marsh variety. Some of the trees begin producing profitable crops at about four years from planting and yield regularly increasing crops every year. The oldest trees of this character under observation were planted in 1898. Other trees of this strain have a tendency to produce large crops one season, followed by lighter crops the next year. Some few trees of this strain are habitually low producers as compared with the most productive trees. As a rule, the most productive trees bear larger crops of first-grade fruits of the most valuable commercial sizes, viz, 80, 64, and 48 fruits per box, than are produced by the low-yielding trees. The large production of high-grade fruits from trees of this strain makes it particularly valuable from the commercial standpoint. The trees of this strain have a spreading habit of growth. The leaves are abundant, large, elliptical, acutely pointed, light green in color, and have large winged petioles. The trees normally bloom in March, and the fruits ripen during the summer months of the following year.

The fruits of the Marsh strain, a typical example of which is shown in Plate V, are oblate in shape, the stem end is usually slightly sunken, and the blossom end even and flattened. This shape is best adapted for handling, and is also a desirable one from the consumer's standpoint. The texture of skin is usually very smooth; color creamy, commonly called ivory white; bloom little or none; rind about one-quarter of an inch in thickness; color of flesh amber; number of sections 12 to 14; rag sparse and tender; vesicles medium in size; core usually open, about 1 inch in diameter; juice abundant, mildly acid, bursting from the fruit when cut, quality excellent, having desirable grapefruit flavor; seeds averaging about three per fruit, which condition is termed "commercially seedless."

Table I shows the detailed performance record of a representative tree of the Marsh strain for the year 1912 and also the summarized record of the same tree for the 6-year period from 1910 to 1915, inclusive. The record of seed content in Table I shows the small number of seeds found in fruits of this strain, several of those examined being entirely seedless.

The superior quality of the fruits of this strain is very marked. It apparently improves in storage under proper conditions, which are an even temperature of about 45° to 50° F. and about 80 to 90 per cent humidity. Under these conditions there is usually an improvement of the fine flavor and the tenderness and palatability of the flesh. For this reason the grapefruit season can be appreciably lengthened by holding the ripe fruits under storage conditions. Another factor of importance in this connection is that consumers can keep the fruits without appreciable deterioration in quality for considerable periods of time.

SEEDY STRAINS.

Two seedy strains have been found which are alike in most characteristics of tree and fruit, but which differ greatly in texture of rind and shape of the fruits.

The trees of the seedy strains, an illustration of which is shown in Plate III, bear relatively very small crops and usually have a very marked alternate-season habit of bearing. The trees have a peculiar and characteristic drooping habit of growth, giving them a dwarfed appearance, which renders their determination an easy matter when once this condition is known. The leaves are rather sparse, small to medium in size, light green in color, and are usually narrow and very sharply pointed.

All of the heavily seeded fruits are objectionable, and their presence in the regular crop tends to depreciate its value as a whole in the markets, in many cases lowering the price received about $1 per box. In addition to this direct cause of loss to the growers, the presence of fruits of the seedy strains impairs the reputation of the entire Marsh variety.

TABLE II.—*Performance record of Marsh grapefruit tree No. 1–15–29, Rough Seedy strain,*[1] *showing the weight and number of fruits of each size and grade and number of seeds counted in detail for the season of 1912 and summarized for the 6-year period, 1910 to 1915, inclusive.*

[The summarized 6-year record illustrates the method of assembling the data of successive seasons for careful comparison and study. The weights are given in pounds and ounces, except that the 6-year totals and the averages are expressed decimally in pounds. This tree is listed in rank 25 of Table III.]

DETAILED RECORD FOR THE SEASON OF 1912.

Sizes of fruits.	Fruits.								Seeds.[2]	
	Ivory-White grade.		Standard grade.		Cull grade.		Total.		Ivory-White grade.	Standard grade.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
	Lbs. oz.		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
112 and smaller	0–11	1	0–11	1			1– 6	2	53	30
96	0– 0	0	3– 4	4			3– 4	4		
80	0– 0	0	9–11	11			9–11	11		
64	3–14	4	7–10	8			11– 8	12	66	36 63
48	1–14	2	6–15	7			8–13	9		
32	3– 2	3	16– 9	15			19–11	18		
24 and larger	12– 0	10	88–11	63			100–11	73	63	55 45
Total	21– 9	20	133– 7	109			155– 0	129	182	229
Grand total					3–5	4	158– 5	133	411	

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[1] NOTES.—Date: May 11, 1912. Poor shape; thick-skinned fruits.

[2] Seeds of cull fruits not counted.

TABLE II.—*Performance record of Marsh grapefruit tree No. 1-15-29, etc.*—Continued.

SUMMARIZED RECORD FOR SIX SEASONS.

Grades and sizes.	1910	1911	1912	1913	1914	1915	Total.	Average.
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	
Ivory-White grade	22-12	137- 2	21- 9	24- 9	88- 4	44-10	338-14	56.5
Standard grade	3- 6	219-10	133- 7	160- 0	122- 5	113- 7	752- 3	125.4
Cull grade	0- 0	0- 0	3- 5	53- 8	1- 7	25-10	83-14	13.9
Grand total	26- 2	356-12	158- 5	238- 0	212- 1	183-11	1,174-15	195.8
Sizes—								
112 and smaller	0- 0	98- 8	1- 6	113- 0	20- 0	16- 8	249- 6	41.6
96	0- 0	57-11	3- 4	39- 4	18-14	9- 6	128- 7	21.4
80	0-14	59- 8	9-11	14- 6	27- 3	19-14	131- 8	21.9
64	1-14	49-12	11- 8	9-15	32-14	14-11	120-10	20.1
48	1- 0	47- 9	8-13	6- 2	29- 7	17- 5	110- 4	18.4
32	2- 1	23- 8	19-11	1-14	22- 9	13- 1	82-12	13.8
24 and larger	20- 5	20- 4	100-11	0- 0	59-10	67- 4	268- 2	44.7
Total	26- 2	356-12	155-0	184- 9	210- 9	158- 1	1,091- 1	181.9
Number of fruits:								
Ivory-White grade	18	152	20	40	95	43	368	61
Standard grade	2	244	109	267	132	101	855	143
Cull grade[1]	0	0	4	116	3	33	156	26
Grand total	20	396	133	423	230	177	1,379	230
Sizes—								
112 and smaller	0	134	2	209	29	22	396	66
96	0	65	4	58	24	11	162	27
80	1	64	11	19	32	21	148	25
64	2	50	12	12	36	14	126	21
48	1	45	9	7	29	16	107	18
32	2	21	18	2	21	11	75	12
24 and larger	14	17	73	0	56	49	209	35
Total	20	396	129	307	227	144	1,223	204
Number of seeds:								
Ivory-White grade—								
112 and smaller	(2)	53	53	29	57	56	248	49.6
64	44	47	66	43	58	60	274	54.8
24 and larger	(2)	50	63	(2)	66	52	231	57.8
Standard grade—								
112 and smaller	(2)	44	30	39	36	64	183	45.8
64	57 55	43	36 63	44	39	59	260	52.0
24 and larger	(2)	51 57	55 45	(2)	45	52	256	51.2
Cull grade—								
112 and smaller	(2)	(2)	(2)	(2)	58	58	190	47.5
64	(2)	(2)	(2)	(2)	(2)	41	120	40.0
24 and larger	(2)	(2)	(2)	(2)	(2)	65	171	56.7
Total	156	345	411	155	359	507	1,933	50.9

[1] The excessive number of culls occurring in 1913 were due to the severe freeze of that season.
[2] Not counted.

ROUGH SEEDY STRAIN.

The fruits of the Rough Seedy strain, an illustration of which is shown in Plate VI, are globular, with the stem end somewhat sunken in a cuplike depression, while the blossom end is also slightly sunken or depressed. The skin is usually coarse in texture and has a dull yellow color, both of which conditions lessen the commercial value of the fruit. The rind is usually about half an inch thick; color of flesh, straw; number of sections 12 to 14; rag usually coarse and unpalatable; vesicles long and large; core usually open, about 1½ inches in diameter; juice usually abundant in quantity, strongly acid, flavor poor, quality very inferior; seeds very large, averaging about 50 per fruit. The great number of seeds found in each fruit is distinctly detrimental to the commercial value of this strain.

Table II shows the detailed performance record of a representative tree of the Rough Seedy strain for the year 1912 and also the summarized record of the same tree for the 6-year period from 1910 to 1915, inclusive. These records, in comparison with those from the tree of the Marsh strain presented in Table I, show the relatively small crops of trees of the Rough Seedy strain and the very high seed content of the fruits of that strain. The trees whose records are shown in Tables I and II grew near each other in the same plat.

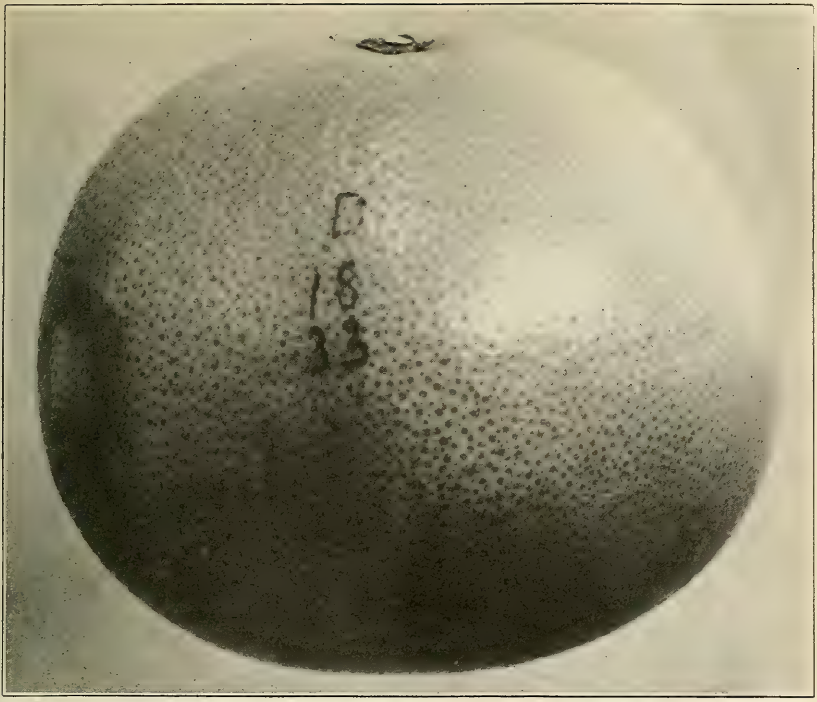
SMOOTH SEEDY STRAIN.

The fruits of the Smooth Seedy strain, an illustration of which is shown in Plate VII, have a flattened shape, smooth texture, and ivory-white color of rind. Entire trees of this strain have been found, and individual fruits and limbs bearing several fruits of this strain are frequently found on trees of the Rough Seedy strain. These fruits are very similar in outward appearance to those of the Marsh strain, but they usually have about the same number of seeds as typical fruits of the Rough Seedy strain, and their characteristics of flesh and juice are similar to those of that strain. Such fruits are so nearly like those of the Marsh strain that it is frequently impossible to sort them out of the general crop, even by the most careful inspection. For this reason, in orchards where trees of this Smooth Seedy strain are found it is especially important to top-work such trees, using select buds from the Marsh strain.

ROUGH STRAIN.

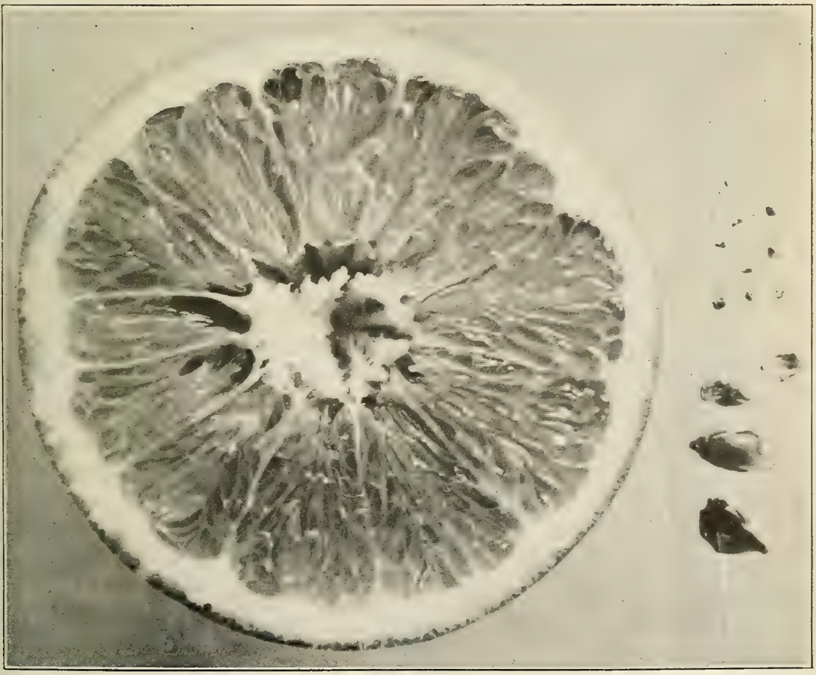
The production of trees of the rough strain is lower than that of trees of the Marsh strain, and the fruits are of inferior commercial quality. The habit of growth of the trees is usually erect, and the vigor of growth is greater than that of the trees of other strains of the variety. An abnormal number of branches of unusually vigorous growth, commonly called suckers, are produced by these trees. These branches usually grow very erect and are irregular in their habits of fruiting. The leaves are very large and usually somewhat sharply pointed and have large winged petioles.

The fruits, an illustration of which is shown in Plate VIII, are globular in shape; size large; skin rough, coarse; color dull yellowish; rind about half an inch thick; rag abundant, bitter; juice scant, lacking in flavor and of inferior quality, and commercially seedless. The fruits of this strain usually ripen later than those of the Marsh strain, even when borne on different branches of the same tree.



P16591—HP

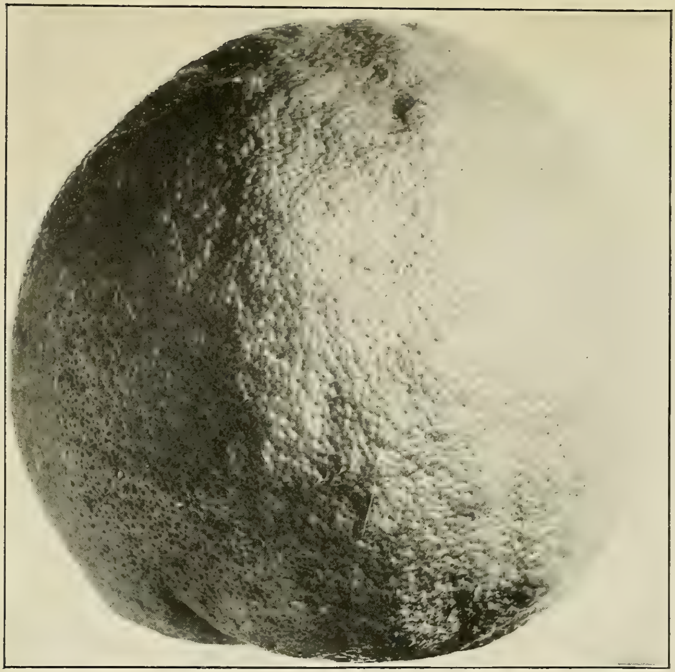
FIG. 1.—SIDE VIEW, SHOWING THE FLATTENED SHAPE AND SMOOTH SKIN CHARACTERISTIC OF FRUITS OF THIS STRAIN. (NINE-TENTHS NATURAL SIZE.)



P16592—HP

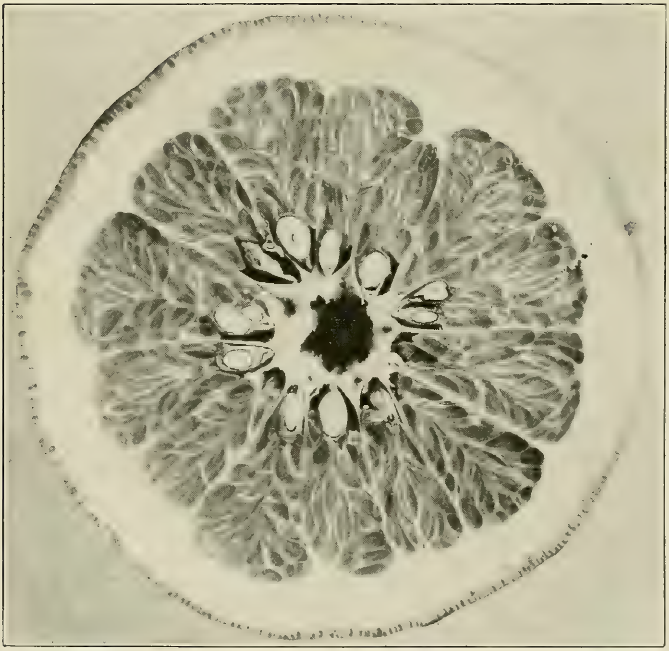
FIG. 2.—CROSS SECTION OF THE SAME FRUIT, SHOWING THE THIN RIND AND FEW SEEDS CHARACTERISTIC OF FRUITS OF THIS STRAIN. (THREE-FOURTHS NATURAL SIZE.)

A TYPICAL FRUIT OF THE MARSH STRAIN OF THE MARSH GRAPEFRUIT.



P9384-HP

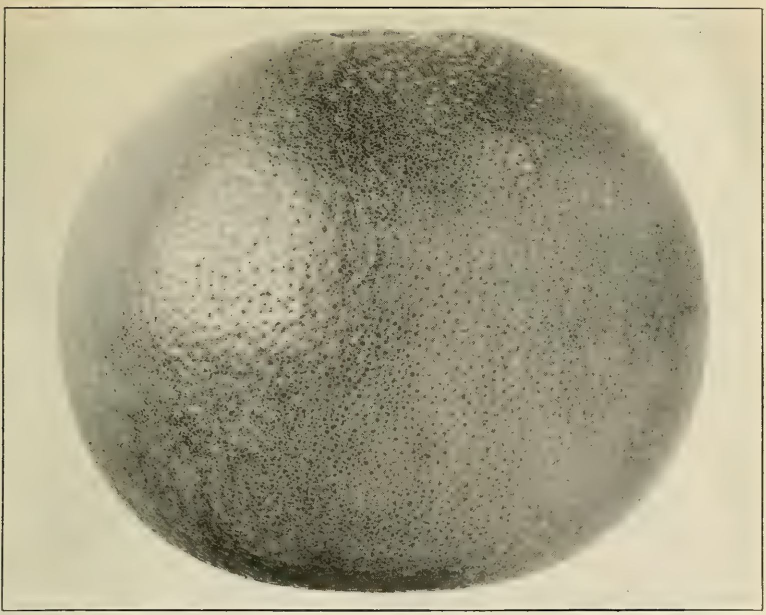
FIG. 1.—SIDE VIEW, SHOWING THE CHARACTERISTIC SHAPE AND APPEARANCE OF THE FRUITS OF THIS STRAIN. (TWO-THIRDS NATURAL SIZE.)



P9385-HP

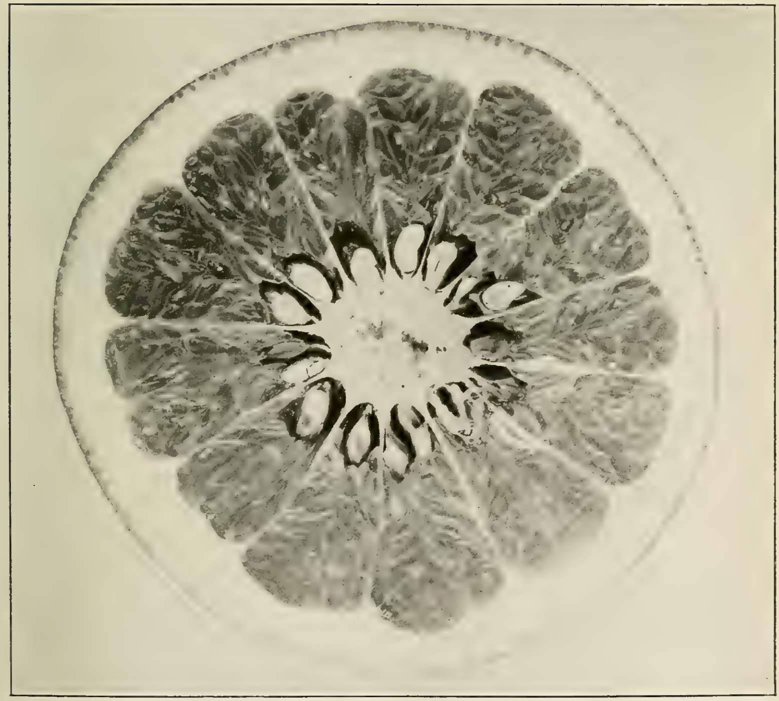
FIG. 2.—CROSS SECTION OF THE SAME FRUIT, SHOWING THE THICKNESS OF RIND AND HEAVILY SEEDED CHARACTER OF THIS FRUIT. (TWO-THIRDS NATURAL SIZE.)

A TYPICAL FRUIT OF THE ROUGH SEEDY STRAIN OF THE MARSH GRAPEFRUIT.



P9020—HP

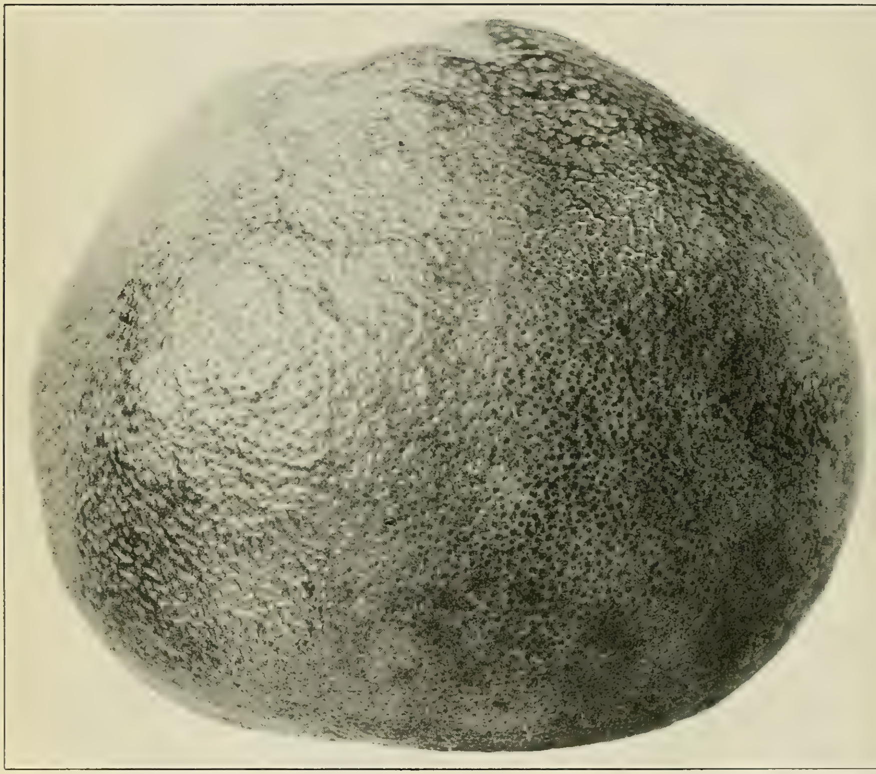
FIG. 1.—SIDE VIEW, SHOWING THE CHARACTERISTIC SHAPE AND APPEARANCE OF THE FRUITS OF THIS STRAIN. THREE-FOURTHS NATURAL SIZE.)



P9021—HP

FIG. 2.—CROSS SECTION OF THE SAME FRUIT, SHOWING THE THICKNESS OF RIND AND HEAVILY SEEDED CHARACTER OF THE FRUITS OF THIS STRAIN. (THREE-FOURTHS NATURAL SIZE.)

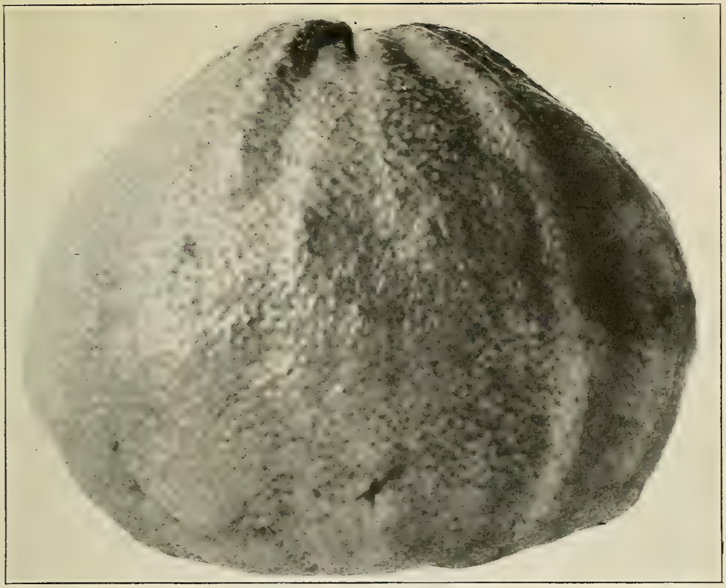
A TYPICAL FRUIT OF THE SMOOTH SEEDY STRAIN OF THE MARSH GRAPEFRUIT.



P9002—HP

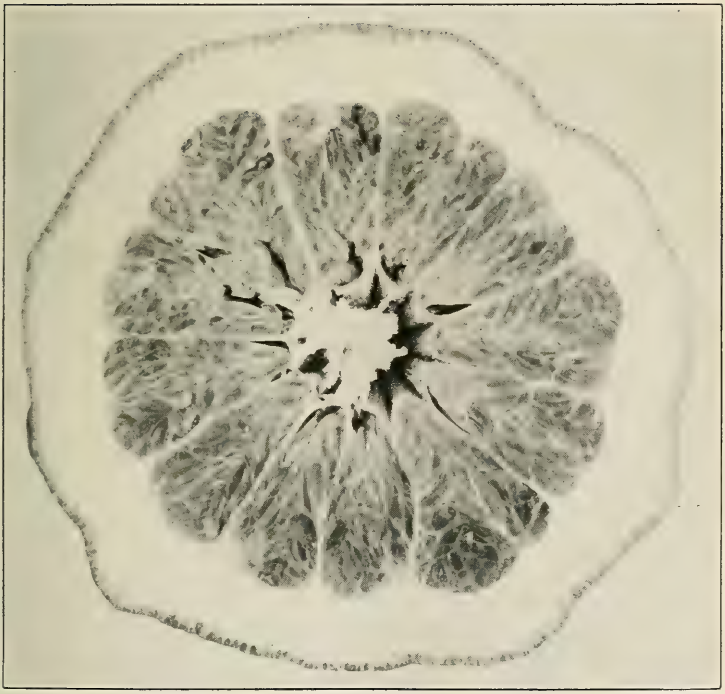
A TYPICAL FRUIT OF THE ROUGH STRAIN OF THE MARSH GRAPEFRUIT, SHOWING ITS CHARACTERISTIC SHAPE AND APPEARANCE.

(Three-fourths natural size.)



P9032–HP

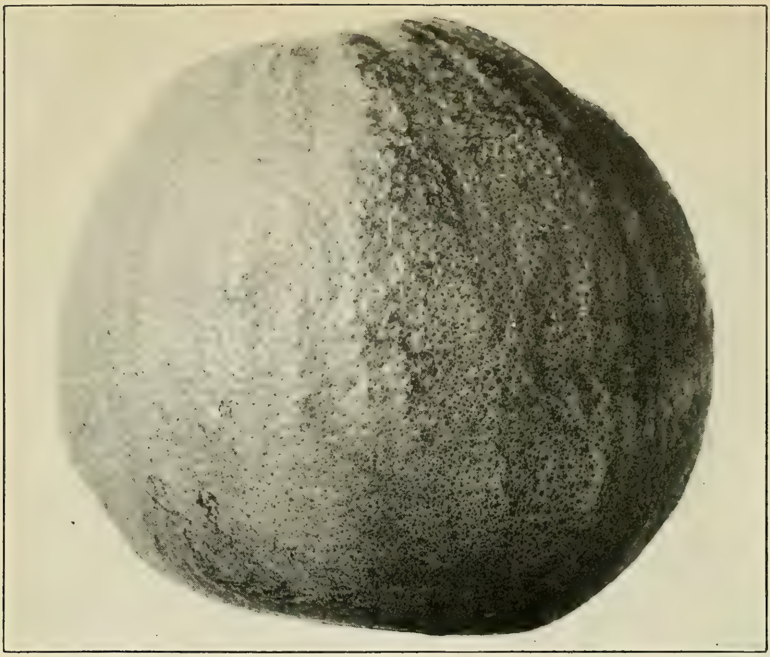
FIG. 1.—SIDE VIEW, SHOWING THE PYRIFORM SHAPE AND DEEPLY FLUTED AND RIDGED CHARACTER OF THE FRUITS OF THIS STRAIN. (SEVEN-TENTHS NATURAL SIZE.)



P9033–HP

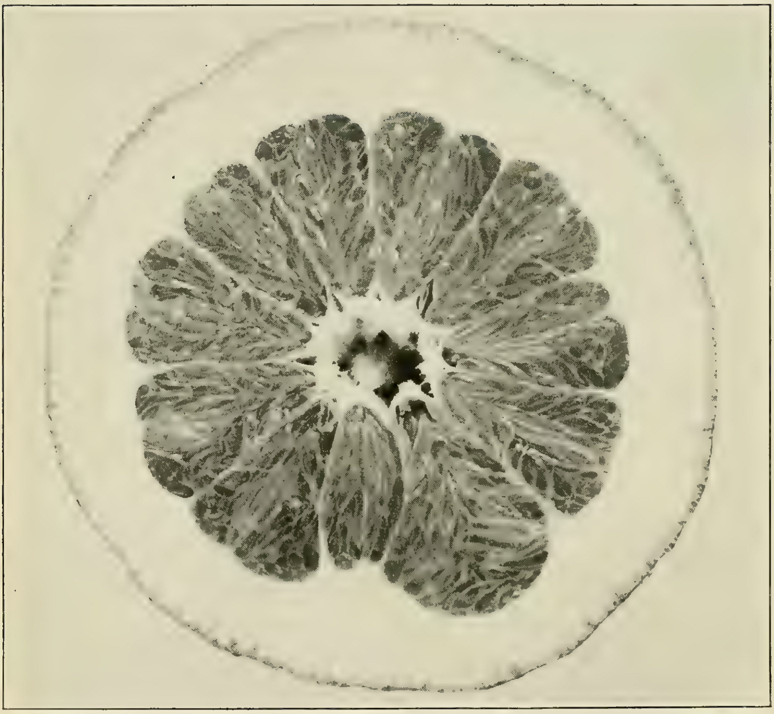
FIG. 2.—CROSS SECTION OF THE SAME FRUIT, SHOWING THE THICKNESS OF THE RIND AND THE CORE CHARACTERISTICS OF THE FRUITS OF THIS STRAIN. (SEVEN-TENTHS NATURAL SIZE.)

A RIBBED FRUIT, A STRIKING VARIATION OF THE MARSH GRAPEFRUIT VARIETY.



P9017–HP

FIG. 1.—SIDE VIEW, SHOWING THE SHAPE AND CORRUGATED APPEARANCE OF THE FRUITS OF THIS STRAIN. (THREE-FOURTHS NATURAL SIZE.)



P9018–HP

FIG. 2.—CROSS SECTION OF THE SAME FRUIT, SHOWING THE THICKNESS OF THE RIND AND OTHER CHARACTERISTICS. (THREE-FOURTHS NATURAL SIZE.)

A TYPICAL FRUIT OF THE CORRUGATED STRAIN OF THE MARSH GRAPEFRUIT.

BELL STRAIN.

The trees of the Bell strain of the Marsh grapefruit, like those of the Rough strain, are usually more vigorous and less productive than those of the true Marsh strain. Sucker growth is very abundant in trees of the Bell strain, giving them an erect habit of growth. The foliage is dense and the leaves are large and sharply pointed. The fruits resemble closely those of the Rough strain, except in shape. They are somewhat pyriform and constricted toward the stem end, giving them a bell-shaped appearance.

In addition to the trees bearing fruits having these general characteristics as a whole, "off-bloom" fruits, developed from flowers blooming out of the regular season, frequently show a marked resemblance to those of the Bell strain. As a rule these fruits are of inferior quality. They do not develop as much sugar or as good flavor as those of the Marsh strain, no matter how long they are allowed to remain on the trees, and they are very undesirable from every standpoint.

Trees bearing a large proportion of fruits of this Bell strain, or those showing a tendency toward the production of fruits of this character, should be eliminated by top-working, and should be carefully avoided in the selection of bud wood for propagation.

ALTERNATE-BEARING STRAIN.

The trees of the Alternate-Bearing strain may be divided into two groups, those bearing fruits with a large number of seeds and those whose fruits are commercially seedless. Several performance-record trees, showing a marked tendency to alternate bearing previous to the freeze of 1913, were so affected by the freeze that their production was lowered and their normal habits of production interfered with for the time being. These trees, at this time, four years after the freeze, show a tendency to an increase in production with a return of their alternate-bearing characteristic.

The important group of trees in the Alternate-Bearing strain is that which resembles closely the Marsh strain except in the characteristic of regularity of production. In habit of growth and foliage characteristics, these trees, so far as observed, can not be distinguished from trees of the Marsh strain. The fruits, except as to number or time of bearing, are so like those of the Marsh strain as to be indistinguishable from them on the basis of our present knowledge of their characteristics.

UNPRODUCTIVE STRAIN.

A smaller proportion of trees of the Unproductive strain has been found in the performance-record plats of grapefruit than has been found in studies of a similar nature with the Washington Navel and Valencia varieties of orange, or of the Eureka and Lisbon varieties of lemon. This condition may be due, in part at least, to the more recent introduction of the Marsh variety and the comparatively small amount of propagation of it, so that only a few bud generations have been available for observation. Recent commercial propagations of this variety have been made, as a rule, with the use of buds selected from trees of the Marsh strain and for the most part by the use of fruit-bearing buds, which explains the presence of only a small number of trees of the undesirable strains.

The trees of the Unproductive strain, and the fruits borne by them, are similar to those of the Marsh strain, except that the trees usually bear relatively fewer first-grade valuable fruits and show a marked alternate-season bearing habit.

INFREQUENT FRUIT VARIATIONS.

Fruits possessing many minor variations of interest and of some importance have been borne by the performance-record trees in addition to the important strains already described. These variations have not been found as frequently as has been the case in the other citrus varieties in the performance-record plats. Fruits are occasionally found that, from outside appearance, more nearly resemble oranges than grapefruits. Some of these variable fruits resemble in flesh and juice characteristics combinations of some of the qualities of oranges, tangerines, and grapefruits.

Another variation occasionally met with is the ribbed fruit, an illustration of which is shown in Plate IX. In this case the fruit is usually bell shaped and the peel has regular longitudinal ridges and depressions, giving it a ribbed or fluted appearance. The rind is usually thick, the rag is rather coarse and bitter, the juice is abundant but of inferior flavor and quality, and the fruits are commercially seedless. These fruits are probably worthless for commercial purposes.

Fruits having raised or sunken sections, or both, are of rather frequent occurrence, particularly on trees of the Seedy and Rough strains.

Several fruits having well-developed navels have been found among the fruits on the performance-record trees. In some cases they were absolutely seedless, while in other instances the fruits contained several seeds. So far, no branch or tree has been found bearing only navel grapefruits. No attempt has been made as yet to isolate a strain of navel grapefruits through bud selection, although it seems probable that this can be done. The presence of a navel in the seedless grapefruit, other things being equal, would likely be a disadvantage except as a distinctive mark for the variety.

Occasional limbs bearing absolutely seedless fruits have been observed in the performance-record trees. Other limbs have been found in these trees bearing fruits all of which were heavily seeded. Frequently individual fruits, either seedless or heavily seeded, are found in trees of the Marsh strain. However, seedless fruits occur much more frequently than heavily seeded ones.

In trees of the Rough Seedy strain, smooth, flattened, seedless fruits characteristic of the Marsh strain have been found. The occurrence of the typical Marsh fruits in the trees of the Rough Seedy strain is as much of a variation as the occurrence of ribbed fruits in trees of the Marsh strain.

In a few cases limbs have been found in trees of the Marsh strain bearing several bell-shaped, corrugated fruits with thick rinds, as illustrated in Plate X. These fruits are produced from flowers which bloom during the normal period and are not the result of flowers developed out of the regular blooming period.

Many other variations in fruits of the Marsh variety of grapefruit have been observed, but are apparently of less importance than the ones cited in the foregoing paragraphs. The studies of these fruits and their relation to bud variation and bud selection are being continued with the object of securing definite and reliable information concerning their characteristics.

SEASONAL FLUCTUATIONS IN PRODUCTION.

The influence of extreme climatic conditions upon the behavior of grapefruit trees, while less marked than in the case of orange and lemon varieties, is, nevertheless, of importance in considering the performance records of the individual trees in these investigations. For instance, the severe freeze during the winter of 1913 upset the behavior of these trees to some extent for the two following seasons. One effect of the freeze was to kill much of the tender fruit-bearing wood. Naturally the loss was greater in the productive than in the unproductive trees. The loss of this wood and the time required for the tree to repair the injury resulted in a reduction of the yield for the following seasons.

Continued dry winds, with a very low condition of relative humidity, sometimes increase the transpiration from the trees beyond the wilting point. The evaporation of soil moisture is also increased to an abnormal degree at such times, thus reducing the moisture available for use by the trees. Such conditions check the development of fruit-bearing wood and influence the amount, texture, and appearance of the rind and size of the fruits. If these dry winds occur during the blooming period, or shortly following that time, an unusual drop of flowers or young fruits occurs, so much so in some cases as to materially reduce the yield of the trees.

In the selection of parent trees for propagation on the basis of their performance records, it is necessary to take into account any unusual climatic or other conditions which may have occurred during the period of study. Of course during long periods of observation the effect of occasional extreme conditions is largely overcome, so that the records become more nearly an absolute guide.

PRESENTATION OF DATA.

The tables and diagrams here presented are prepared from the performance records of Marsh grapefruit trees in two plats, one of 25 trees planted in 1898 and the other of 52 trees planted in 1903. For convenient reference in the following discussion these plats will be designated A and B, respectively. These records cover the six years from 1910 to 1915, inclusive. However, the culls were not recorded in 1910 or 1911, so that the data shown for the fruit of that grade represent conditions during four seasons only. In these plats there are representative trees of five of the six recognized important strains of the Marsh variety. In plat A, the older trees, there are 19 trees of the Marsh strain, 5 of the Seedy strains, and 1 of the Rough strain. In plat B there are 40 trees of the Marsh strain, 9 of the Alternate-Bearing strain, and 3 of the Unproductive strain. These plats are both located as solid blocks of trees in larger commercial plantings. It is interesting to note that only 76 per cent and 76.9 per cent, respectively, of trees of the Marsh strain were found in the two plats, and approximately the same proportions of typical Marsh trees are found in the two orchards as a whole.

The performance records, descriptions, and illustrations from photographs here presented only partially indicate the characteristics of the various strains. The trees and fruits must be seen and studied personally before their true differences can be fully appreciated and the importance of these variations in commercial fruit growing really understood. On this account the determination of trees from which to secure bud wood for propagation should not be made entirely on the basis of the performance records of the trees. The most reliable selection will be made by a comparative study in the orchard of the performance records of the trees, the habits of growth and appearance of the trees, and the character of the fruit on the trees. Such a selection can be intelligently made only by some one who, through close study and observation of the trees themselves, has gained an intimate knowledge of the interrelation of tree characteristics and crop production.

In Tables III and IV are presented the individual-tree performance records of all the trees in the investigational plats on which data have been secured for the 6-year period. These show the production by weight and number of fruits of each grade and size for each year and the average annual production for the 6-year period both by grades and sizes. The basis of ranking the trees in these tables is their average total annual production expressed in pounds, without regard to the quality or uniformity of the fruit. This arbitrary basis is adopted only because of the impracticability of working out a system to show the actual relative commercial value of each individual tree; hence, the order in which the trees are here listed is not always an indication of their true value, either as fruit producers or as sources of desirable bud wood for propagation.

In expressing the averages of weights in these tables only one decimal place has been retained, and in the figures showing the averages of the number of fruits occurring in different groups no decimal has been retained except where the average is less than unity; hence, it will be found that the totals of averages will sometimes vary slightly from the average of the totals of the corresponding numbers.

Cull fruits were not recorded for the years 1910 and 1911, hence the average production of that grade is not strictly comparable with the averages of the other grades, and the total of the averages of the three grades is not equivalent to the average of the total crops.

Because it is impracticable to assort the culls by sizes, the fruits listed by sizes under the heading "Total crop" represent only the total commercial crops, being equal to the total crop exclusive of the culls.

In determining the seed content of fruits on the different trees, counts are made, when possible, of the seeds in a small, a medium, and a large fruit of each of the three grades. In this way a record is secured of the actual number of seeds in nine fruits from each tree, yearly, and it is thought that this system gives a fairly accurate indication of the relative seediness of the fruits of the different trees. Counts were not made on plat B until 1912, and no determinations were made in the Cull grade on either plat until 1914. In 1910, only one fruit of the Ivory-White grade and two fruits of the Standard grade were used for this purpose. In 1911 and 1912, three fruits from the Ivory-White grade and six from the Standard grade were used, and in 1913 three from both the Ivory-White and Standard grades were cut. In 1914 and 1915, three fruits from each of the three grades were examined, when possible. The general average for each year is secured on the basis of the actual number of fruits examined and not from an average of the averages of the different grades. No record of the occurrence of variable fruits was made until 1912. The increase in the number of such fruits recorded during recent years is due to the fact that the observers have gradually become familiar with additional variable forms. Practically all the variable fruits recorded are of minor importance, such as those with ridges, raised or sunken sections, or creases.

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive.*

[The weights of annual production are expressed in pounds and ounces, but the fractional averages are stated decimally in pounds. The cull fruits were not recorded for the first two years, so the average production of that grade is not comparable with the other grades, and the total of the averages of the three grades is not equivalent to the average of the total crops. The fruits listed by sizes under the side heading "Total crop" do not include the Cull grade.]

INVESTIGATIONAL PERFORMANCE RECORD, PLAT A, PLANTED IN 1898.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
1. Tree No. 1-14-30, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	187– 9	180	15– 5	23	2–15	4	18– 1	21	27–13	30	22–12	23	25– 6	23	75– 5	56	0	....
1911	109– 9	133	50– 7	72	11– 7	14	11– 4	13	10–11	11	12– 5	12	1– 1	1	12– 6	10	2.00	....
1912	369–13	419	48–13	74	36–10	49	56–14	71	63– 5	71	61– 7	63	37– 0	36	65–12	55	1.00	....
1913	149–12	223	59– 0	106	36– 0	51	19– 5	26	14– 3	18	5–15	7	5– 9	6	9–12	9	1.00	....
1914	240–12	277	25– 9	41	42– 1	55	32–12	36	50–10	57	42–11	45	16– 3	16	30–14	27	3.33	....
1915	292–11	335	75– 9	108	33– 8	41	56– 8	64	50– 0	51	30–14	30	17– 0	16	29– 4	25	4.00	....
Average	225.0	261	45.8	71	27.1	36	32.5	39	36.1	40	29.3	30	17.0	16	37.2	30	1.89	....
Standard grade—																		
1910	304– 7	307	32–10	49	15– 9	20	35–11	41	42–12	46	38–10	38	41– 2	37	98– 1	76	0	....
1911	532–11	717	343– 9	511	45– 2	54	54– 7	62	45– 9	48	26– 1	26	9– 9	9	8– 6	7	2.80	....
1912	212– 7	273	69– 9	111	28–10	37	42– 4	51	27–15	31	24– 3	25	8– 7	8	11– 7	10	2.17	....
1913	238– 7	333	182– 1	254	30– 9	46	17– 1	23	3– 6	4	4– 6	5	0– 0	0	1– 0	1	1.33	....
1914	218–12	272	51–15	84	41– 7	53	34– 3	41	37–11	42	23– 6	24	20–11	20	9– 7	8	3.00	....
1915	192– 3	238	77– 4	113	33–10	40	34–14	39	20–15	22	13– 6	13	7– 6	7	4–12	4	3.67	....
Average	283.2	357	126.2	187	32.5	41	36.4	42	29.7	32	21.7	22	14.6	14	22.2	18	2.16	....
Cull fruits—																		
1912	8– 0	19	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1913	72– 3	193	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1914	18– 0	54	....	......	....	......	....	......	....	......	....	......	....	......	....	......	2.00	....
1915	21– 4	36	....	......	....	......	....	......	....	......	....	......	....	......	....	......	5.33	....
Average	29.9	76	....	......	....	......	....	......	....	......	....	......	....	......	....	......	3.67	....

Total crop—																	
1910	492– 0	487	47–15	72	18– 8	24	53–12	62	70– 9	76	61– 6	61	66– 8	60	173– 6	132	0	....
1911	642– 4	850	394– 0	583	56– 9	68	65–11	75	56– 4	59	38– 6	38	10–10	10	20–12	17	2.50	....
1912	590– 4	711	118– 6	185	65– 4	86	99– 2	122	91– 4	102	85–10	88	45– 7	44	77– 3	65	1.56	2
1913	460– 6	749	241– 1	360	66– 9	97	36– 6	49	17– 9	22	10– 5	12	5– 9	6	10–12	10	1.17	6
1914	477– 8	603	77– 8	125	83– 8	108	66–15	77	88– 5	99	66– 1	69	36–14	36	40– 5	35	2.78	3
1915	506– 2	609	152–13	221	67– 2	81	91– 6	103	70–15	73	44– 4	43	24– 6	23	34– 0	29	4.44	9
Average	**528.1**	**668**	**171.9**	**258**	**59.6**	**77**	**68.9**	**81**	**65.8**	**72**	**51.0**	**52**	**31.6**	**30**	**59.4**	**48**	**2.08**	**5.00**
2. Tree No. 1-16-31, Marsh strain:																	
Ivory-White grade—																	
1910	279– 3	256	10– 4	15	10– 3	13	20–12	24	28– 3	30	36–13	36	45– 1	41	127–15	97	0	....
1911	186– 0	226	79– 0	114	30– 6	36	21– 7	24	16– 2	17	16– 2	16	10– 2	9	12–13	10	.67	....
1912	389–12	494	96– 8	152	58– 9	80	76– 3	94	57–10	67	49–13	51	29– 9	30	21– 8	20	1.67	....
1913	86– 4	111	15– 3	27	12– 4	18	10– 6	14	16– 4	20	11–10	13	5–12	6	14–13	13	.33	....
1914	231–15	285	48–11	76	35– 2	47	34–15	43	51– 9	59	31–14	33	15–15	15	13–13	12	4.33	....
1915	249– 6	289	67– 6	97	33–14	41	55– 6	62	37– 6	39	21– 6	21	17–10	16	16– 6	13	7.33	....
Average	237.1	277	52.8	80	30.1	39	36.5	43	34.5	39	27.9	28	20.6	19	34.5	28	2.39	....
Standard grade—																	
1910	193– 6	176	7– 3	11	7– 6	9	16– 2	18	22– 6	23	21– 4	20	27– 9	25	91–13	70	.50	....
1911	249–13	336	138–12	217	31– 3	37	27– 3	30	16–15	18	21– 8	21	10– 8	10	3–12	3	1.83	....
1912	179– 0	245	73– 8	121	22– 9	30	32–12	40	25–14	29	15– 6	16	7– 0	7	1–15	2	1.83	....
1913	182– 3	271	70– 9	133	30–14	45	21– 8	29	19–10	24	14– 4	16	8– 8	9	16–14	15	2.67	....
1914	146– 0	188	36–10	61	26– 4	34	28– 0	34	27– 7	31	13– 5	14	7–14	8	6– 8	6	3.00	....
1915	93–12	118	42– 2	62	12– 4	15	18– 6	21	6–10	7	6– 4	6	4–10	4	3– 8	3	3.00	....
Average	174.0	222	61.5	101	21.7	29	24.0	29	19.7	22	15.3	16	11.0	11	20.8	16	2.14	....
Cull fruits—																	
1912	5– 6	13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	42– 6	107	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	40–12	86	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.67	....
1915	30– 0	32	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.67	....
Average	29.6	60	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.67	....
Total crop—																	
1910	472– 9	432	17– 7	26	17– 9	22	36–14	42	50– 9	53	58– 1	56	72– 5	66	219–12	167	.33	....
1911	435–13	562	217–12	331	61– 9	73	48–10	54	33– 1	35	37–10	37	20–10	19	16– 9	13	1.44	....
1912	574– 2	752	170– 0	273	81– 2	110	108–15	134	83– 8	96	65– 3	67	36– 9	37	23– 7	22	1.78	0
1913	310–13	489	85–12	160	43– 2	63	31–14	43	35–14	44	25–14	29	14– 4	15	31–11	28	1.50	3
1914	418–11	559	85– 5	137	61– 6	81	62–15	77	79– 0	90	45– 3	47	23–13	23	20– 5	18	3.33	10
1915	373– 2	439	109– 8	159	46– 2	56	73–12	83	44– 0	46	27–10	27	22– 4	20	19–14	16	5.00	2
Average	**430.9**	**539**	**114.3**	**181**	**51.8**	**68**	**60.5**	**72**	**54.3**	**61**	**43.3**	**44**	**31.6**	**30**	**55.3**	**44**	**2.23**	**3.75**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT A, PLANTED IN 1898—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
3. Tree No. 1-15-30, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	232- 2	221	18-13	26	6- 8	8	22- 3	25	29-11	31	35- 7	34	35- 8	32	84- 0	65	0	....
1911	164- 6	198	68-15	97	25-12	31	20- 8	23	21-12	23	11- 7	11	5- 7	5	10- 9	8	3.00	....
1912	308-10	362	50- 6	77	30- 2	40	55- 4	68	55- 6	63	35-12	38	40- 3	40	41- 9	36	1.33	....
1913	167-12	248	83- 4	146	20- 5	29	11-13	16	20- 1	24	12- 8	14	6- 0	6	13-13	13	1.33	....
1914	181- 5	210	30-12	49	16- 8	22	22-10	28	27-12	31	37- 2	38	21- 2	20	25- 7	22	4.00	....
1915	238-11	258	33- 2	47	23- 0	28	44-13	51	39- 5	41	38-15	38	27-15	26	31- 9	27	5.33	....
Average	215.5	250	47.5	74	20.4	26	29.5	35	32.3	35	28.5	29	22.7	22	34.5	29	2.50	....
Standard grade—																		
1910	142- 7	147	19- 8	29	16-10	20	14- 4	16	18- 3	19	15- 9	15	19- 7	17	38-14	31	0	....
1911	382- 2	521	248-12	376	48- 2	57	37-15	42	19-11	21	14- 0	13	8-12	8	4-14	4	3.20	....
1912	224- 6	299	85-11	139	41- 1	53	34- 3	41	30-11	34	10- 4	11	10-15	11	11- 9	10	0.67	....
1913	177- 3	317	117- 6	239	27- 4	39	13-12	18	10-12	13	2-12	3	2- 1	2	3- 4	3	1.00	....
1914	128- 3	151	25-14	42	18- 3	23	17-11	21	19- 8	21	21-12	22	9- 7	9	15-12	13	2.67	....
1915	109- 9	133	39- 0	55	14-12	18	29- 9	33	16- 2	17	6-15	7	1- 0	1	2- 3	2	6.00	....
Average	194.0	261	89.4	146	27.6	35	24.6	29	19.2	21	11.9	12	8.6	8	12.7	10	2.26	....
Cull fruits—																		
1912	5-13	13	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1913	71- 9	227	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1914	9-11	26	....	......	....	......	....	......	....	......	....	......	....	......	....	......	4.33	....
1915	14-13	24	....	......	....	......	....	......	....	......	....	......	....	......	....	......	6.67	....
Average	25.5	73	....	......	....	......	....	......	....	......	....	......	....	......	....	......	5.50	....

Total crop—																		
1910	374- 9	368	38- 5	55	23- 2	28	36- 7	41	47-14	50	51- 0	49	54-15	49	122-14	96	0	....
1911	546- 8	719	317-11	473	73-14	88	58- 7	65	41- 7	44	25- 7	24	14- 3	13	15- 7	12	3.13	....
1912	538-13	674	136- 1	216	71- 3	93	89- 7	109	86- 1	97	46- 0	49	51- 2	51	53- 2	46	.89	1
1913	416- 8	792	200-10	385	47- 9	68	25- 9	34	30-13	37	15- 4	17	8- 1	8	17- 1	16	1.17	0
1914	319- 3	387	56-10	91	34-11	45	40- 5	49	47- 4	52	58-14	60	30- 9	29	41- 3	35	3.67	5
1915	363- 1	415	72- 2	102	37-12	46	74- 6	84	55- 7	58	45-14	45	28-15	27	33-12	29	6.00	4
Average	**426.4**	**559**	**136.9**	**220**	**48.0**	**61**	**54.1**	**64**	**51.5**	**56**	**40.4**	**41**	**31.3**	**30**	**47.2**	**39**	**2.48**	**2.50**
4. Tree No. 1-16-30, Marsh strain:																		
Ivory-White grade—																		
1910	335-14	356	49- 2	70	34- 7	43	51- 7	59	52- 8	55	49- 8	48	21- 1	19	77-13	62	1.00	....
1911	175- 3	193	42- 4	59	28-11	34	20-12	23	22-10	23	19-14	19	24-14	22	16- 2	13	1.33	....
1912	312-10	389	51- 2	79	43- 6	59	75- 6	96	58- 4	69	40-12	44	21- 6	22	22- 6	20	.33	....
1913	66- 6	86	14- 8	25	9-11	14	6- 8	9	8- 2	10	8-12	10	10- 4	11	8- 9	7	2.33	....
1914	217-13	247	31- 2	52	24- 9	32	32-13	39	27-10	31	34-10	35	19-14	19	47- 3	39	2.67	....
1915	255- 2	283	47- 0	67	39- 6	48	52-12	59	36- 4	37	35-14	35	17-14	16	26- 0	21	2.67	....
Average	227.2	259	39.2	59	30.0	38	39.9	47	34.2	38	31.6	32	19.2	18	33.0	27	1.72	....
Standard grade—																		
1910	161- 8	182	34-14	55	19-12	24	26-12	30	20-14	22	15-11	15	9- 0	8	34- 9	38	.50	....
1911	218- 5	274	93- 1	145	29- 2	34	30- 5	33	32- 1	32	14-14	14	5- 8	5	13- 6	11	2.80	....
1912	243- 9	343	141-14	222	27- 2	36	34- 7	42	14-14	17	13-14	15	7- 1	7	4- 5	4	2.40	....
1913	167-11	249	70- 5	130	26- 0	37	13- 8	18	22- 6	27	15- 2	17	13-14	14	6- 8	6	.67	....
1914	121- 7	149	21- 5	37	15- 9	20	8-13	11	15- 2	23	27- 4	28	18-10	18	14-12	12	2.00	....
1915	109- 0	131	40- 0	59	14- 2	17	18- 2	20	12- 8	13	11- 2	11	5-10	5	7- 8	6	2.33	....
Average	170.2	221	66.9	108	22.0	23	22.0	26	19.7	22	16.3	17	10.0	10	13.5	11	1.78	....
Cull fruits—																		
1912	11- 6	22	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1913	54- 4	125	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1914	12-12	43	....	......	....	......	....	......	....	......	....	......	....	......	....	......	2.67	....
1915	23- 1	34	....	......	....	......	....	......	....	......	....	......	....	......	....	......	4.33	....
Average	25.4	56	....	......	....	......	....	......	....	......	....	......	....	......	....	......	3.50	....
Total crop—																		
1910	497- 6	538	84- 0	125	54- 3	67	78- 3	89	73- 6	77	65- 3	63	30- 1	27	112- 6	90	.67	....
1911	393- 8	467	135- 5	204	57-13	68	51- 1	56	54-11	55	34-12	33	30- 6	27	29- 8	24	2.25	....
1912	567- 9	754	193- 0	301	70- 8	95	109-13	138	73- 2	86	54-10	59	28- 7	29	26-11	24	1.63	0
1913	288- 5	460	84-13	155	35-11	51	20- 0	27	30- 8	37	23-14	27	24- 2	25	15- 1	13	1.50	0
1914	352- 0	439	52- 7	89	40- 2	52	41-10	50	42-12	54	61-14	63	38- 8	37	61-15	51	2.44	3
1915	387- 3	448	87- 0	126	53- 8	65	70-14	79	48-12	50	47- 0	46	23- 8	21	33- 8	27	3.11	1
Average	**414.3**	**518**	**106.1**	**167**	**52.0**	**66**	**61.9**	**73**	**53.0**	**60**	**47.9**	**49**	**29.2**	**28**	**46.5**	**38**	**1.93**	**1.00**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT A, PLANTED IN 1898—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
5. Tree No. 1-15-31, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	237- 8	213	9-13	15	7- 3	9	19-15	23	29- 0	29	22- 0	21	24- 2	22	125- 7	94	1.00	....
1911	94- 6	121	45-13	67	15- 5	19	10- 8	12	10-12	12	5- 0	5	2- 4	2	4-12	4	.33	....
1912	308- 0	372	66- 0	97	25-14	35	64- 9	81	51- 5	59	42- 0	45	35- 1	35	23- 3	20	5.00	....
1913	45- 3	58	13- 3	22	3- 7	5	3-12	5	6- 9	8	5- 5	6	5-15	6	7- 0	6	0	....
1914	219- 9	300	56- 5	89	30- 9	41	32- 2	40	42- 0	74	25- 8	26	18- 4	18	14-13	12	2.67	....
1915	149- 9	170	38- 8	57	20- 3	24	26-12	30	23- 9	24	14-14	14	8-13	8	16-14	13	6.00	....
Average	175.7	206	38.3	58	17.1	22	26.3	32	27.2	34	19.1	20	15.7	15	32.0	25	2.50	....
Standard grade—																		
1910	157- 2	157	14-13	23	7- 4	9	17- 6	20	20- 4	22	21- 8	21	19-13	18	56- 2	44	0	....
1911	411-12	570	257- 5	395	53-13	70	24- 7	28	44- 3	47	20- 4	20	4- 7	4	7- 5	6	4.40	....
1912	251- 1	329	87- 7	140	31-11	42	46-11	57	35- 9	40	27-10	29	11- 5	11	10-12	10	4.50	....
1913	177- 6	284	97-13	185	21-15	31	18-10	25	20- 7	24	6- 6	7	10- 3	10	2- 0	2	3.33	....
1914	158- 1	197	37- 4	59	25- 2	33	25-12	32	31- 7	36	17- 8	18	11- 6	11	9-10	8	4.33	....
1915	104- 8	127	44- 0	64	12- 2	14	21- 4	24	11- 4	11	8-10	8	2- 2	2	5- 2	4	5.33	....
Average	210.0	277	89.8	144	25.3	33	25.7	31	27.2	30	17.0	17	9.9	10	15.2	12	3.65	....
Cull fruits—																		
1912	18- 7	38	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	96- 7	243	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	12- 4	43	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.00	....
1915	13- 4	18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.33	....
Average	35.1	86	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.17	....

1910	394–10	370	24–10	38	14– 7	18	37– 5	43	49– 4	51	43– 8	42	43–15	40	181– 9	138	.33	....
1911	506– 2	691	303– 2	462	69– 2	89	34–15	40	54–15	59	25– 4	25	6–11	6	12– 1	10	2.88	....
1912	577– 8	739	153– 7	237	57– 9	77	111– 4	138	86–14	99	69–10	74	46– 6	46	33–15	30	4.67	0
1913	319– 0	585	111– 0	207	25– 6	36	22– 6	30	27– 0	32	11–11	13	16– 2	16	9– 0	8	1.67	0
1914	390– 8	540	93– 9	148	55–11	74	57–14	72	73– 7	110	43– 0	44	29–10	29	24– 7	20	4.43	1
1915	267– 5	315	82– 8	121	32– 5	38	48– 0	54	34–13	35	23– 8	22	10–15	10	22– 0	17	5.89	3
Average	**409.2**	**540**	**128.0**	**202**	**42.4**	**55**	**52.0**	**63**	**54.4**	**64**	**36.1**	**37**	**25.6**	**25**	**47.2**	**37**	**3.32**	**1.00**
6. Tree No. 1–17–30, Marsh strain:																		
Ivory-White grade—																		
1910	277–13	254	18– 1	25	14– 2	17	29– 4	32	27–15	28	30–14	29	49– 8	44	108– 1	79	0	
1911	291– 3	307	49– 9	68	39– 5	47	46– 7	50	39–15	41	37– 2	35	41– 4	37	37– 9	29	1.00	....
1912	143–13	134	6– 5	9	9– 9	12	13– 8	16	9– 2	10	15–10	16	13– 8	13	76– 3	58	1.33	....
1913	63– 4	83	11–12	20	11–10	17	4–14	7	11–14	15	6– 4	7	9– 4	10	7–10	7	.33	....
1914	271–11	318	47– 2	73	43– 5	56	33–14	41	44– 6	50	34–13	36	29–11	29	38– 8	33	1.67	....
1915	194– 4	202	23–12	33	27– 6	32	43– 7	47	28–15	29	23–10	22	19–14	18	27– 4	21	2.33	....
Average	207.0	216	26.1	38	24.2	30	28.6	32	27.0	29	24.7	24	27.2	25	49.2	38	1.11	....
Standard grade—																		
1910	187– 1	177	23– 6	33	8– 6	10	17– 4	19	27–11	28	20– 7	19	29–10	26	60– 5	42	5.00	....
1911	308– 6	344	80–11	113	43– 8	51	69– 6	74	34–14	35	36– 3	34	11– 5	10	32– 7	27	1.67	....
1912	130– 7	133	18– 6	27	8–14	11	14–13	17	11– 4	12	16–12	17	14– 2	13	46– 4	36	3.50	....
1913	242–13	395	132– 5	252	34–10	51	27– 3	37	18–12	23	18–13	21	7–11	8	3– 7	3	.67	....
1914	122–13	165	51–14	82	19– 4	25	16– 8	20	17– 8	20	10– 3	11	4– 2	4	3– 6	3	2.67	....
1915	59–10	68	16–13	25	4– 2	5	11– 8	13	8–14	9	8– 8	8	2– 4	2	7– 9	6	5.00	....
Average	175.2	214	53.9	89	19.8	26	26.1	30	19.8	21	18.5	18	11.5	11	25.6	19	3.09	....
Cull fruits—																		
1912	4– 0	8	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1913	84– 5	213	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1914	22– 4	56	....	......	....	......	....	......	....	......	....	......	....	......	....	......	5.33	....
1915	24– 3	36	....	......	....	......	....	......	....	......	....	......	....	......	....	......	5.67	....
Average	33.7	78	....	......	....	......	....	......	....	......	....	......	....	......	....	......	5.50	....
Total crop—																		
1910	464–14	431	41– 7	58	22– 8	27	46– 8	51	55–10	56	51– 5	48	79– 2	70	168– 6	121	3.75	....
1911	599– 9	651	130– 4	181	82–13	98	115–13	124	74–13	76	73– 5	69	52– 9	47	70– 0	56	1.44	....
1912	278– 4	275	24–11	36	18– 7	23	28– 5	33	20– 6	22	32– 6	33	27–10	26	122– 7	94	2.78	0
1913	390– 6	691	144– 1	272	46– 4	68	32– 1	44	30–10	38	25– 1	28	16–15	18	11– 1	10	.50	0
1914	416–12	539	99– 0	155	62– 9	81	50– 6	61	61–14	70	45– 0	47	33–13	33	41–14	36	3.22	4
1915	278– 1	306	40– 9	58	31– 8	37	54–15	60	37–13	38	32– 2	30	22– 2	20	34–13	27	4.33	0
Average	**404.6**	**482**	**80.0**	**127**	**44.0**	**56**	**54.7**	**62**	**46.8**	**50**	**43.2**	**42**	**38.7**	**36**	**74.8**	**57**	**2.67**	**1.0**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT A, PLANTED IN 1898—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
7. **Tree No. 1-14-32**, Rough strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	287-15	301	30- 5	45	24-11	31	41-10	49	50- 9	54	40-13	39	31-11	29	68- 4	54	0	....
1911	169- 3	195	55-14	76	26-12	33	23- 2	26	21- 1	22	16-13	16	10-11	10	14-14	12	2.00	....
1912	300- 9	404	117- 7	187	43- 4	59	41- 4	52	38- 0	44	32-12	35	20- 4	20	7-10	7	2.33	....
1913	103-14	161	44- 7	82	22- 1	33	14- 4	19	9-10	12	8-13	10	2-12	3	1-15	2	0	....
1914	187- 8	219	20- 7	32	20- 3	27	25- 6	32	34- 6	40	36-15	40	19-12	20	30- 7	28	1.33	....
1915	56- 3	70	26- 4	39	6-10	8	5- 6	6	5- 9	6	4- 2	4	3- 6	3	4-14	4	4.33	....
Average	184.2	225	49.1	77	23.9	32	25.2	31	26.5	30	23.4	24	14.7	14	21.4	18	1.67	....
Standard grade—																		
1910	190- 6	211	31- 3	48	13- 0	16	24- 9	29	38- 0	41	31- 6	31	19-13	18	32- 7	28	.50	....
1911	317- 1	381	120-15	174	53- 8	64	44- 8	49	37-14	39	23- 7	23	18-13	17	18- 0	15	2.40	....
1912	218-12	308	102- 4	169	34- 8	46	32- 3	40	23- 4	27	12-11	13	4-15	5	8-15	8	1.17	....
1913	153- 7	281	118- 0	232	21- 4	31	8- 3	11	4- 1	5	0-14	1	0- 0	0	1- 1	1	2.67	....
1914	162- 9	204	35-11	59	24- 6	32	21-10	27	33-13	39	17-10	19	16- 5	16	13- 2	12	.67	....
1915	182- 6	228	88- 7	128	29- 4	35	26-13	30	19- 8	18	9- 6	9	5- 8	5	3- 8	3	6.33	....
Average	204.1	269	82.8	135	29.3	37	26.3	31	26.1	28	15.9	16	10.9	10	12.8	11	2.29	....
Cull fruits—																		
1912	6- 8	15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	56- 0	140	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	15- 0	36	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.33	....
1915	19-14	30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.33	....
Average	24.3	55	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.33	....

Total crop—																		
1910	478– 5	512	61– 8	93	37–11	47	66– 3	78	88– 9	95	72– 3	70	51– 8	47	100–11	82	.33	....
1911	486– 4	576	176–13	250	80– 4	97	67–10	75	58–15	61	40– 4	39	29– 8	27	32–14	27	2.25	....
1912	525–13	727	219–11	356	77–12	105	73– 7	92	61– 4	71	45– 7	48	25– 3	25	16– 9	15	1.56	....
1913	313– 5	582	162– 7	314	43– 5	64	22– 7	30	13–11	17	9–11	11	2–12	3	3– 0	3	1.33	2
1914	365– 1	459	56– 2	91	44– 9	59	47– 0	59	68– 3	79	54– 9	59	36– 1	36	43– 9	40	1.78	3
1915	258– 7	328	114–11	167	35–14	43	32– 3	36	25– 1	24	13– 8	13	8–14	8	8– 6	7	4.67	2
Average	**404.5**	**531**	**131.9**	**212**	**53.2**	**69**	**51.5**	**62**	**52.6**	**58**	**39.3**	**40**	**25.6**	**24**	**34.2**	**29**	**1.99**	**1.75**
8. Tree No. 1–14–33, Marsh strain:																		
Ivory-White grade—																		
1910	307– 4	264	3– 6	5	7– 0	9	9– 9	11	25– 1	27	34– 7	35	23– 2	22	204–11	155	0	....
1911	237– 1	244	29–15	41	31– 0	38	16– 2	18	32–12	34	40– 8	40	38–11	36	48– 1	37	2.67	....
1912	211–15	238	28– 2	44	14– 9	19	24– 2	30	37–14	43	28– 4	30	30– 0	30	49– 0	42	2.33	....
1913	120– 9	197	67– 1	125	27–10	40	9–14	13	8–11	11	4– 8	5	1–14	2	0–15	1	2.00	....
1914	289– 2	419	152–14	252	52– 0	70	29– 3	37	27– 9	32	18– 4	19	4–14	5	4– 6	4	4.00	....
1915	13– 4	17	8– 8	12	0–12	1	0– 0	0	1–13	2	0– 0	0	1– 1	1	1– 2	1	4.00	....
Average	196.5	230	48.3	80	22.2	30	14.8	18	22.3	25	21.0	22	16.6	16	51.4	40	2.50	....
Standard grade—																		
1910	222– 4	214	12– 8	19	8–10	11	19– 7	23	20– 4	22	21–14	22	34– 0	32	105– 9	85	0	....
1911	387–15	462	142– 1	199	71– 0	82	55–13	62	62– 1	65	33– 5	33	17– 9	16	6– 2	5	2.33	....
1912	162– 2	214	62– 9	101	22– 0	29	26– 6	32	19– 0	21	11–13	12	9– 6	9	11– 0	10	2.00	....
1913	140– 0	270	110– 6	229	12–14	19	8–13	12	6– 3	8	0– 0	0	1–12	2	0– 0	0	3.50	....
1914	160– 2	245	91– 0	162	23– 4	31	18– 9	23	15– 3	17	7–15	8	3– 0	3	1– 3	1	2.33	....
1915	20– 3	21	4– 5	5	2– 6	3	2–12	3	0– 0	0	3–14	4	2– 4	2	4–10	4	5.00	....
Average	182.1	238	70.5	119	23.3	29	22.0	26	20.4	22	13.1	13	11.3	11	21.4	18	2.53	....
Cull fruits—																		
1912	1– 6	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	72– 0	197	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	12– 2	30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.00	....
1915	3–13	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.00	....
Average	22.3	59	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.50	....
Total crop—																		
1910	529– 8	478	15–14	24	15–10	20	29– 0	34	45– 5	49	56– 5	57	57– 2	54	310– 4	240	0	....
1911	625– 0	706	172– 0	240	102– 0	120	71–15	80	94–13	99	73–13	73	56– 4	52	54– 3	42	1.67	....
1912	375– 7	456	90–11	145	36– 9	48	50– 8	62	56–14	64	40– 1	42	39– 6	39	60– 0	52	2.11	3
1913	332– 9	664	177– 7	354	40– 8	59	18–11	25	14–14	19	4– 8	5	3–10	4	0–15	1	2.60	0
1914	461– 6	694	243–14	414	75– 4	101	47–12	60	42–12	49	26– 3	27	7–14	8	5– 9	5	4.11	1
1915	37– 4	43	12–13	17	3– 2	4	2–12	3	1–13	2	3–14	4	3– 5	3	5–12	5	4.50	0
Average	**393.5**	**507**	**118.8**	**199**	**45.5**	**59**	**36.8**	**44**	**42.7**	**47**	**34.1**	**35**	**27.9**	**27**	**72.8**	**58**	**2.50**	**1.0**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT A, PLANTED IN 1898—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
9. Tree No. 1-18—30, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	315– 8	242	4– 5	6	4– 1	5	7– 0	8	12– 6	13	21–11	21	22– 8	20	243– 9	169	0	....
1911	418– 4	295	4– 0	7	3–15	5	14–13	16	23–10	24	27– 3	26	20– 0	18	324–11	199	2.00	....
1912	76– 5	73	2– 1	3	0–12	1	3– 2	4	1–12	2	6– 4	7	9– 6	9	53– 0	47	1.00	....
1913	114– 3	144	11–10	21	19–10	29	15–14	22	17– 1	22	7– 3	9	11– 0	12	31–13	29	.33	....
1914	357–11	434	73– 9	112	63–12	85	47– 0	57	62– 8	72	48–15	51	27–12	27	34– 3	30	2.67	....
1915	194– 7	189	14– 4	20	11–11	14	25– 2	28	20–14	22	30– 8	29	27– 6	25	64–10	51	5.00	....
Average	246.1	230	18.3	28	17.3	23	18.8	23	23.0	26	23.6	24	19.7	19	125.3	87	1.83	....
Standard grade—																		
1910	175– 7	157	10– 1	15	7–14	10	10–13	12	14– 7	15	26–12	25	18– 9	16	86–15	64	1.00	....
1911	121– 4	107	7–12	11	2–10	3	4– 6	5	12–12	13	13–12	13	9–13	9	70– 3	53	2.67	....
1912	52–15	52	4– 2	6	0–12	1	7– 7	9	4–12	5	4–12	5	5– 4	5	25–14	21	3.50	....
1913	180– 0	281	81– 7	153	20– 9	31	23– 9	33	21– 0	27	17– 3	20	23– 9	8	9– 8	9	2.00	....
1914	179–10	231	54– 5	86	34– 7	45	25– 8	31	31– 9	36	13– 9	14	10–14	11	9– 6	8	4.33	....
1915	62–14	64	8– 0	11	3– 4	4	11–12	13	7–12	8	10– 4	10	6– 6	6	15– 8	12	4.00	....
Average	128.7	149	27.6	47	11.6	16	13.9	17	15.4	17	14.4	14	9.6	9	36.2	28	2.92	....
Cull fruits—																		
1912	2– 1	4	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1913	65– 3	313	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1914	22–13	59	....	......	....	......	....	......	....	......	....	......	....	......	....	......	2.33	....
1915	12–13	17	....	......	....	......	....	......	....	......	....	......	....	......	....	......	6.00	....
Average	25.7	98	....	......	....	......	....	......	....	......	....	......	....	......	....	......	4.17	....

Total crop—																		
1910	490–15	399	14– 6	21	11–15	15	17–13	20	26–13	28	48– 7	46	41– 1	36	330– 8	233	.67	....
1911	539– 8	402	11–12	18	6– 9	8	19– 3	21	36– 6	37	40–15	39	29–13	27	394–14	252	2.44	....
1912	131– 5	129	6– 3	9	1– 8	2	10– 9	13	6– 8	7	11– 0	12	14–10	14	78–14	68	2.67	0
1913	359– 6	738	93– 1	174	40– 3	60	39– 7	55	38– 1	49	24– 6	29	17–12	20	41– 5	38	1.17	1
1914	560– 2	724	127–14	198	98– 3	130	72– 8	88	94– 1	108	62– 8	65	38–10	38	43– 9	38	3.11	2
1915	270– 2	270	22– 4	31	14–15	18	36–14	41	28–10	30	40–12	39	33–12	31	80– 2	63	5.00	4
Average	**391.9**	**444**	**45.9**	**75**	**28.9**	**39**	**32.7**	**40**	**38.4**	**43**	**38.0**	**38**	**29.3**	**28**	**161.5**	**115**	**2.51**	**1.75**
10. Tree No. 1-17—33, Marsh strain:																		
Ivory-White grade—																		
1910	265– 5	215	1–15	3	1–12	2	7– 4	8	10–11	11	11– 2	11	27–14	26	204–11	154	1.00	....
1911	418– 8	410	34– 0	45	34–14	42	49–15	56	45–10	48	52–12	55	58–15	54	142– 6	110	1.00	....
1912	146– 2	162	20– 8	31	8– 6	11	21– 7	26	22–11	27	17– 8	18	20–10	20	35– 0	29	2.67	....
1913	68– 2	98	23– 1	42	10–10	16	10–15	15	5– 0	6	6–12	8	2–10	3	9– 2	8	0	....
1914	381– 8	534	175–13	289	65– 0	87	56–15	70	40–14	46	25–14	27	4– 2	4	13– 8	11	3.33	....
1915	76– 2	93	22–10	36	8–14	11	15– 0	17	12–12	13	9–14	10	2– 4	2	4–12	4	6.33	....
Average	225.9	252	46.3	74	21.6	28	26.9	32	22.9	25	20.6	21	19.4	18	68.1	53	2.39	....
Standard grade—																		
1910	109–14	98	6– 7	9	7– 8	9	5– 8	6	9–11	10	6– 3	6	14–14	13	59–11	45	4.00	....
1911	240–15	263	55– 5	80	24– 6	29	37– 6	41	28–12	29	32– 2	31	24–10	23	38– 6	30	3.50	....
1912	103– 5	121	19–15	34	8– 3	11	15–15	19	14– 8	16	9– 0	9	9– 6	9	26– 6	23	2.83	....
1913	225–15	385	145–15	278	37–15	54	13–14	19	13– 6	17	11–14	14	0–15	1	2– 0	2	2.33	....
1914	119–11	168	46–12	80	29– 7	40	12–15	16	15–14	18	6– 8	7	2– 4	2	5–15	5	1.00	....
1915	19– 1	22	6–14	10	1–10	2	0– 0	0	1–14	2	3– 0	3	4– 5	4	1– 6	1	6.00	....
Average	136.5	176	46.9	82	18.2	24	14.3	17	14.0	15	11.4	12	9.4	9	22.3	17	3.28	....
Cull fruits—																		
1912	12– 1	21	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	143– 0	411	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	14– 7	32	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.67	....
1915	7– 2	14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.00	....
Average	44.2	120	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.34	....
Total crop—																		
1910	375– 3	313	8– 6	12	9– 4	11	12–12	14	20– 6	21	17– 5	17	42–12	39	264– 6	199	3.00	....
1911	659– 7	673	89– 5	125	59– 4	71	87– 5	97	74– 6	77	84–14	86	83– 9	77	180–12	140	2.67	....
1912	261– 8	304	40– 7	65	16– 9	22	37– 6	45	37– 3	43	26– 8	27	30– 0	29	61– 6	52	2.78	0
1913	437– 1	894	169– 0	320	48– 9	70	24–13	34	18– 6	23	18–10	22	3– 9	4	11– 2	10	1-17	0
1914	515–10	734	222– 9	369	94– 7	127	69–14	86	56– 2	64	32– 6	34	6– 6	6	19– 7	16	3.67	3
1915	102– 5	129	29– 8	46	10– 8	13	15– 0	17	14–10	15	12–14	13	6– 9	6	6– 2	5	5.44	1
Average	**391.9**	**508**	**93.2**	**156**	**39.8**	**52**	**41.2**	**49**	**36.9**	**41**	**32.1**	**33**	**28.8**	**27**	**90.5**	**70**	**3.12**	**1.00**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT A, PLANTED IN 1898—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
11. Tree No. 1-18—29, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	294–12	233	1– 8	2	3– 5	4	7–14	9	13– 7	14	16– 2	16	21– 3	19	231– 5	169	0.	....
1911	382– 7	292	5– 4	7	7– 6	9	18– 4	20	25– 3	26	36– 0	35	34–10	31	255–12	164	2.33	....
1912	152–10	144	2–12	4	4– 6	6	9–14	12	14– 0	16	15– 4	16	14– 6	14	92– 0	76	1.67	....
1913	79– 4	101	10–11	19	8– 8	13	9–10	13	19– 3	24	10– 6	12	9– 7	10	11– 7	10	0.	....
1914	296– 0	373	64– 3	102	57–11	77	48– 6	60	51–14	60	26–15	29	23–13	24	23– 2	21	3.33	....
1915	212– 3	191	9– 1	12	6– 0	7	20– 8	23	18–10	19	23–14	23	27–12	25	106– 6	82	2.67	....
Average	236.2	222	15.6	24	14.5	19	19.1	23	23.7	26	21.4	22	21.9	21	120.0	87	1.67	....
Standard grade—																		
1910	149– 4	126	7– 1	10	3–15	5	4– 7	5	8– 0	8	15–13	15	16– 2	14	93–14	69	3.00	....
1911	121– 4	117	11– 1	16	9–10	12	5– 5	6	17–10	18	7– 3	7	18–12	17	51–11	41	3.00	....
1912	70–14	72	6–15	10	4–13	6	5– 4	6	4– 7	5	11–12	12	7– 3	7	30– 8	26	3.00	....
1913	204–10	311	54– 3	106	45–11	69	34– 6	47	29–10	38	11– 5	13	16– 7	18	13– 0	20	1.67	....
1914	162– 8	216	56– 3	92	20– 8	28	23– 9	29	31– 2	36	17– 9	19	4–15	5	8–10	7	3.00	....
1915	69– 7	68	9– 2	13	3– 5	4	7– 2	8	7–13	8	6– 5	6	10–10	9	25–12	20	4.00	....
Average	129.7	152	24.1	42	14.7	21	13.3	17	16.5	19	11.6	12	12.3	11	37.2	31	2.95	....
Cull fruits—																		
1912	2– 0	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	68–12	162	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	11–12	38	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.00	....
1915	14–12	20	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.33	....
Average	24.3	56	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.17	....

Total crop—																		
1910	444– 0	359	8– 9	12	7– 4	9	12– 5	14	21– 7	22	31–15	31	37– 5	33	325– 3	238	2.00	....
1911	503–11	409	16– 5	23	17– 0	21	23– 9	26	42–13	44	43– 3	42	53– 6	48	307– 7	205	2.78	....
1912	225– 8	220	9–11	14	9– 3	12	15– 2	18	18– 7	21	27– 0	28	21– 9	21	122– 8	102	2.56	0
1913	352–10	574	64–14	125	54– 3	82	44– 0	60	48–13	62	21–11	25	25–14	28	24– 7	30	.83	0
1914	470– 4	627	120– 6	194	78– 3	105	71–15	89	83– 0	96	44– 8	48	28–12	29	31–12	28	2.44	8
1915	296– 6	279	18– 3	25	9– 5	11	27–10	31	26– 7	27	30– 3	29	37–12	34	132– 2	102	3.33	1
Average	**382.1**	**411**	**39.7**	**66**	**29.2**	**40**	**32.4**	**40**	**40.2**	**45**	**33.1**	**34**	**34.1**	**32**	**157.2**	**118**	**3.49**	**2.25**
12. Tree No. 1-16-32, Marsh strain:																		
Ivory-White grade—																		
1910	266– 4	229	5– 8	8	0–12	1	15–12	18	24– 7	26	27–10	27	33– 3	30	159– 0	119	1.00	....
1911	165–14	230	100–14	155	21–12	27	10– 2	12	17–14	21	11– 0	11	3– 2	3	1– 2	1	2.00	....
1912	331–14	430	103– 6	161	42– 2	58	59– 2	75	52– 3	60	37– 4	40	20–11	21	17– 2	15	1.33	....
1913	65– 9	85	16–14	29	6– 2	9	6–14	9	10–11	13	8– 8	9	9–14	10	6–10	6	.67	....
1914	212– 3	244	16–12	27	22–12	31	32– 1	40	48–14	56	42–10	44	22– 3	22	26–15	24	2.67	....
1915	166–10	194	56–12	80	26– 8	32	23– 6	26	20– 8	21	16–15	16	11– 6	10	11– 3	9	4.33	....
Average	201.4	235	50.0	77	20.0	26	24.6	30	29.1	33	24.0	25	16.8	16	37.0	29	2.00	....
Standard grade—																		
1910	151– 6	129	8–12	14	2– 6	3	6–13	8	14– 6	15	18– 7	18	18–14	17	61–12	54	0	....
1911	315–11	458	217– 9	348	35– 3	43	26– 8	30	19–10	21	10– 2	10	5–11	5	1– 0	1	.80	....
1912	201– 0	288	109–10	178	29–13	39	24–12	31	25– 5	28	7– 8	8	1–14	2	2– 2	2	2.40	....
1913	153–11	249	83–13	161	25–14	36	14–14	19	14– 3	17	7–15	9	3–12	4	3– 4	3	1.33	....
1914	106–13	132	17– 1	29	22– 0	29	13–12	17	24–14	28	11–10	12	14– 3	14	3– 5	3	3.33	....
1915	75–11	93	37– 8	55	4–10	5	17– 8	19	2–15	3	4– 6	4	3– 6	3	5– 6	4	5.67	....
Average	164.0	225	79.1	131	20.0	26	17.3	21	16.9	19	10.0	10	8.0	8	12.8	11	2.26	....
Cull fruits—																		
1912	7– 3	16	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	47–15	105	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	9– 0	30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.00	....
1915	16– 2	27	....	....	....	....	....	....	....	....	....	....	....	....	....	....	7.00	....
Average	20.1	45	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.00	....
Total crop—																		
1910	397–10	358	14– 4	22	3– 2	4	22– 9	26	38–13	41	46– 1	45	52– 1	47	220–12	173	.33	....
1911	481– 9	688	318– 7	503	56–15	70	36–10	42	37– 8	42	21– 2	21	8–13	8	2– 2	2	1.25	....
1912	540– 1	734	213– 0	339	71–15	97	83–14	106	77– 8	88	44–12	48	22– 9	23	19– 4	17	2.00	0
1913	267– 3	439	100–11	190	32– 0	45	21–12	28	24–14	30	16– 7	18	13–10	14	9–14	9	1.00	2
1914	328– 0	406	33–13	56	44–12	60	45–13	57	73–12	84	54– 4	56	36– 6	36	30– 4	27	3.00	3
1915	258– 7	314	94– 4	135	31– 2	37	40–14	45	23– 7	24	21– 5	20	14–12	13	16– 9	13	5.50	0
Average	**378.8**	**490**	**129.1**	**208**	**40.0**	**52**	**41.9**	**51**	**46.0**	**52**	**34.0**	**35**	**24.7**	**24**	**49.8**	**40**	**2.18**	**1.25**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT A, PLANTED IN 1898—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
13. Tree No. 1-18-32, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	246– 9	221	9– 4	13	6– 8	8	17–15	20	19– 5	20	24–12	24	34–15	32	133–14	104	0	....
1911	384– 3	393	37– 5	51	42– 5	50	58–10	65	47–11	49	64– 5	63	49– 2	45	84–13	70	1.67	....
1912	149–15	159	12–11	19	8– 3	11	21–12	26	19– 0	21	15– 4	19	21–13	21	51– 4	42	2.33	....
1913	45–10	63	8–13	16	9– 4	14	6– 9	9	8– 8	11	3–10	4	5–12	6	3– 2	3	0	....
1914	223–14	286	59– 8	94	34– 8	46	42– 6	53	38– 6	44	20–15	22	16– 5	16	11–14	11	4.67	....
1915	224–14	238	32–12	46	28–12	34	46– 2	51	31–14	33	23–14	23	22– 0	20	39– 8	31	3.00	....
Average	212.5	227	26.7	40	21.6	27	32.2	37	27.5	30	25.5	26	25.0	23	54.1	44	1.95	....
Standard grade—																		
1910	179– 9	172	18– 6	27	6–15	8	18– 1	20	20– 9	21	26– 2	25	14– 0	13	75– 8	58	1.00	....
1911	136–13	144	18– 7	28	18– 3	21	17–11	19	18– 7	19	21–15	21	20– 5	18	21–13	18	2.33	....
1912	114– 8	127	23– 3	35	8– 9	11	16– 4	19	12–10	14	9– 6	10	7– 2	7	37– 6	31	2.50	....
1913	181– 6	290	80– 7	154	34– 0	51	19– 5	27	23–11	31	12– 8	15	5– 8	6	5–15	6	.33	....
1914	146–12	201	62–10	103	21–15	29	17– 1	21	20– 1	23	15– 7	16	7– 6	7	2– 4	2	4.33	....
1915	66–14	73	10–10	16	7– 6	9	11– 9	13	7–14	8	11– 3	11	8– 8	8	9–12	8	4.33	....
Average	137.6	168	35.6	60	16.2	22	16.7	20	17.2	19	16.1	16	10.5	10	25.4	20	2.47	....
Cull fruits—																		
1912	2–14	6	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1913	95– 8	214	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1914	43– 8	72	....	......	....	......	....	......	....	......	....	......	....	......	....	......	1.67	....
1915	19– 8	22	....	......	....	......	....	......	....	......	....	......	....	......	....	......	3.00	....
Average	40.3	79	....	......	....	......	....	......	....	......	....	......	....	......	....	......	2.35	....

Total crop—																		
1910	426- 2	393	27-10	40	13- 7	16	36- 0	40	39-14	41	50-14	49	48-15	45	209- 6	162	.67	....
1911	521- 0	537	55-12	79	60- 8	71	76- 5	84	66- 2	68	86- 4	84	69- 7	63	106-10	88	2.11	....
1912	267- 5	294	35-14	54	16-12	22	38- 0	45	31-10	35	24-10	29	28-15	28	88-10	73	2.44	2
1913	322- 8	567	89- 4	170	43- 4	65	25-14	36	32- 3	42	16- 2	19	11- 4	12	9- 1	9	.17	0
1914	414- 2	559	122- 2	197	56- 7	75	59- 7	74	58- 7	67	36- 6	38	23-11	23	14- 2	13	3.56	1
1915	311- 4	333	43- 6	62	36- 2	43	57-11	64	39-12	41	35- 1	34	30- 8	24	49- 4	39	3.44	0
Average	**377.1**	**447**	**62.3**	**100**	**37.8**	**49**	**48.9**	**57**	**44.7**	**49**	**41.6**	**42**	**35.5**	**33**	**79.5**	**64**	**2.07**	**0.75**
14. Tree No. 1-16-29, Marsh strain:																		
Ivory-White grade—																		
1910	243-11	237	14- 2	21	11-10	15	22-15	26	31-10	33	31- 5	31	47- 9	44	84- 8	67	0	....
1911	185-15	205	34- 2	47	27- 7	33	38- 0	43	20- 4	21	22- 8	22	21-10	20	22- 0	19	1.33	....
1912	296- 0	337	34-10	55	22-12	30	46- 6	57	49- 7	57	37- 9	41	40- 2	41	65- 2	56	1.33	....
1913	48-14	69	10-15	20	11-10	17	6-12	9	9- 7	12	4- 4	5	3-12	4	2- 2	2	.33	....
1914	261- 0	307	31- 2	50	33-14	45	49-13	61	66- 6	74	29- 1	30	29- 2	28	21-10	19	3.33	....
1915	121-12	119	11- 0	15	3- 2	4	15- 6	17	18- 8	19	17- 6	17	15- 6	14	41- 0	33	3.00	....
Average	192.9	212	22.7	35	18.4	24	29.9	36	32.6	36	23.7	24	26.3	25	39.4	33	1.55	....
Standard grade—																		
1910	117- 4	113	3-13	7	4- 0	5	17- 6	19	12- 9	13	14- 1	14	18-12	17	46-11	38	0	....
1911	246- 0	288	78-13	114	40- 0	48	36- 7	40	30- 0	31	23- 6	23	16- 4	15	21- 2	17	1.50	....
1912	142- 6	174	29- 5	48	24-13	33	21- 3	26	17- 0	19	15- 6	16	13- 4	13	21- 7	19	2.67	....
1913	206- 9	344	115- 1	226	31-10	46	20- 7	27	19-13	24	9-11	11	2- 5	3	7-10	7	4.33	....
1914	160- 5	197	24-15	43	24-11	33	22- 0	27	46-10	52	20-14	22	13- 9	13	7-10	7	2.67	....
1915	69-11	74	15-12	23	6- 4	8	7- 2	8	6- 0	6	10- 4	10	8-12	6	15- 9	13	2.33	....
Average	157.0	198	44.6	77	21.9	29	20.7	24	22.0	24	15.6	16	12.1	11	20.0	17	2.25	....
Cull fruits—																		
1912	4- 3	8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	53-10	142	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	11-12	36	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.67	....
1915	14- 5	16	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.00	....
Average	21.0	51	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.34	....
Total crop—																		
1910	360-15	350	17-15	28	15-10	20	40- 5	45	44- 3	46	45- 6	45	66- 5	61	131- 3	105	0	....
1911	431-15	493	112-15	161	67- 7	81	74- 7	83	50- 4	52	45-14	45	37-14	35	43- 2	36	1.44	....
1912	442- 9	519	63-15	103	47- 9	63	67- 9	83	66- 7	76	52-15	57	53- 6	54	86- 9	75	2.22	0
1913	309- 1	555	126- 0	246	43- 4	63	27- 3	36	29- 4	36	13-15	16	6- 1	7	9-12	9	2.33	1
1914	433- 1	540	56- 1	93	58- 9	78	71-13	88	113- 0	126	49-15	52	42-11	41	29- 4	26	3.56	4
1915	205-12	209	26-12	38	9- 6	12	22- 8	25	24- 8	25	27-10	27	24- 2	20	56- 9	46	3.78	2
Average	**363.9**	**444**	**67.3**	**112**	**40.3**	**53**	**50.6**	**60**	**54.6**	**60**	**39.3**	**40**	**38.4**	**36**	**59.4**	**50**	**2.22**	**1.75**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT A, PLANTED IN 1898—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
15. **Tree** No. 1-17-29, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	187- 9	159	3- 4	5	7- 9	9	11-13	13	17- 1	17	23-11	22	31-14	27	92- 5	66	....	....
1911	273- 6	323	91- 0	130	49- 6	59	36- 7	41	38- 8	41	26-15	26	9- 8	9	21-10	17	2.33	....
1912	182- 8	161	2-12	4	8-10	11	9- 6	11	8- 4	9	16-10	17	17-11	17	119- 3	92	1.33	....
1913	44- 5	63	14-11	27	7-14	12	4- 6	6	4-14	6	4- 6	5	1-14	2	6- 4	5	1.33	....
1914	274- 6	333	53- 2	81	43-15	58	44-10	55	47-14	55	45-14	48	20- 8	20	18- 7	16	3.67	....
1915	165- 4	148	8- 6	12	6-14	8	13-12	15	20- 4	20	19-14	18	18-10	16	77- 8	59	2.67	....
Average	187.9	198	28.9	43	20.7	26	20.1	24	22.8	24	22.9	23	16.7	15	55.8	43	1.89	....
Standard grade—																		
1910	118-15	104	8- 9	13	4-13	6	10-14	12	4-14	5	7- 5	7	20-15	18	61- 9	43	.50	....
1911	251- 7	314	118- 0	170	32- 2	38	40- 0	44	40- 7	42	13- 2	13	3- 4	3	4- 8	4	.80	....
1912	129- 7	136	13- 6	21	9- 8	12	18- 7	22	14- 2	15	14-15	15	24- 9	23	34- 8	28	1.50	....
1913	215- 8	356	119- 5	228	36-15	54	20- 4	27	27- 2	34	7- 0	8	3-12	4	1- 2	1	.67	....
1914	137-15	181	51- 8	82	16- 7	22	16- 8	20	23-12	27	17- 4	18	6- 0	6	6- 8	6	4.67	....
1915	68- 8	66	9- 8	13	6- 3	7	6- 4	7	7- 0	7	9-12	9	3- 5	3	26- 8	20	2.00	....
Average	153.6	193	53.4	88	17.7	23	18.7	22	19.6	22	11.6	11	10.3	10	22.4	17	1.69	....
Cull fruits—																		
1912	8- 4	12	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1913	54-10	127	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1914	17-14	51	....	......	....	......	....	......	....	......	....	......	....	......	....	......	2.00	....
1915	12- 6	15	....	......	....	......	....	......	....	......	....	......	....	......	....	......	4.33	....
Average	23.3	51	....	......	....	......	....	......	....	......	....	......	....	......	....	......	3.17	....

Total crop—																		
1910	306– 8	263	11–13	18	12– 6	15	22–11	25	21–15	22	31– 0	29	52–13	45	153–14	109	.33	....
1911	524–13	637	209– 0	300	81– 8	97	76– 7	85	78–15	83	40– 1	39	12–12	12	26– 2	21	1.38	....
1912	320– 3	309	16– 2	25	18– 2	23	27–13	33	22– 6	24	31– 9	32	42– 4	40	153–11	120	1.44	0
1913	314– 7	546	134– 0	255	44–13	66	24–10	33	32– 0	40	11– 6	13	5–10	6	7– 6	6	1.00	0
1914	430– 3	565	104–10	163	60– 6	80	61– 2	75	71–10	82	63– 2	66	26– 8	26	24–15	22	3.44	5
1915	246– 2	229	17–14	25	13– 1	15	20– 0	22	27– 4	27	29–10	27	21–15	19	104– 0	79	3.00	2
Average	**357.0**	**425**	**82.2**	**131**	**38.4**	**49**	**38.8**	**46**	**42.4**	**46**	**34.5**	**34**	**27.0**	**25**	**18.3**	**60**	**1.77**	**1.75**
16. Tree No. 1–17–31, Marsh strain:																		
Ivory-White grade—																		
1910	243–14	203	3– 9	5	2– 7	3	6– 3	7	12– 7	13	15– 7	15	27– 5	25	176– 8	135	3.00	....
1911	267– 3	241	6– 5	9	11–11	14	21–11	24	24–15	26	29– 6	29	24–12	23	148– 7	116	3.00	....
1912	307– 2	327	20– 0	31	13– 5	18	33–10	43	36– 4	43	38– 6	41	46– 2	47	119– 7	104	1.00	....
1913	45– 6	54	2–13	5	3–15	6	6– 9	9	10– 5	13	4– 5	5	4–13	5	12–10	11	1.33	....
1914	345–12	449	98– 7	154	70– 0	93	49– 8	62	64–15	75	27– 8	30	18–12	19	16–10	16	1.67	....
1915	80–14	91	23– 2	32	7–10	9	14– 0	16	11–12	12	9– 6	9	9– 2	8	5–14	5	5.00	....
Average	215.0	228	25.7	39	18.2	24	21.9	27	26.8	31	20.7	22	21.8	21	79.9	65	2.50	....
Standard grade—																		
1910	129– 9	111	5–14	9	1–11	2	5– 5	6	11–10	12	6– 1	6	17–12	16	81– 4	60	1.00	....
1911	129– 0	128	12–15	19	6– 7	8	14– 0	15	19–10	20	11–12	11	16– 2	15	48– 2	40	1.50	....
1912	134– 2	145	9– 0	15	9– 8	13	15– 6	19	17– 9	20	20– 4	22	12–10	13	49–13	43	1.67	....
1913	183–10	250	45– 4	81	27– 8	41	16– 8	23	31– 7	40	19–12	23	14– 2	15	29– 1	27	1.00	....
1914	111– 3	153	43–13	72	19– 5	26	16– 7	20	18–12	22	5– 8	6	3–14	4	3– 8	3	2.67	....
1915	24– 3	27	8– 2	11	2– 8	3	2–11	3	2– 2	2	4– 0	4	0– 0	0	4–12	4	2.67	....
Average	118.6	136	20.8	35	11.1	15	11.7	14	16.8	19	11.2	12	10.8	11	36.1	29	1.75	....
Cull fruits—																		
1912	2–12	7	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	69– 7	141	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	21– 3	53	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.67	....
1915	13–12	22	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.67	....
Average	26.8	56	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.17	....
Total crop—																		
1910	373– 7	314	9– 7	14	4– 2	5	11– 8	13	24– 1	25	21– 8	21	45– 1	41	257–12	195	1.00	....
1911	396– 3	369	19– 4	28	18– 2	22	35–11	39	44– 9	46	41– 2	40	40–14	38	196– 9	156	2.00	....
1912	444– 0	479	29– 0	46	22–13	31	49– 0	62	53–13	63	58–10	63	58–12	60	169– 4	147	1.44	3
1913	298– 7	445	48– 1	86	31– 7	47	23– 1	32	41–12	53	24– 1	28	18–15	20	41–11	38	2.33	7
1914	478– 2	655	142– 4	226	89– 5	119	65–15	82	83–11	97	33– 0	36	22–10	23	20– 2	19	2.89	3
1915	118–13	140	31– 4	43	10– 2	12	16–11	19	13–14	14	13– 6	13	9– 2	8	10–10	9	3.44	3
Average	**351.5**	**400**	**46.5**	**74**	**29.3**	**39**	**33.6**	**41**	**43.6**	**50**	**31.9**	**34**	**32.6**	**32**	**116.0**	**94**	**2.18**	**4.00**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT A, PLANTED IN 1898—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
17. Tree No. 1-17-32, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	208-9	207	23-12	35	7-14	10	20-11	24	23-8	25	30-14	30	30-12	28	71-2	55	0	......
1911	228-10	262	65-12	93	45-13	52	35-6	40	27-13	29	21-7	21	13-7	12	19-0	15	2.67	......
1912	260-8	294	33-4	53	27-2	36	26-9	33	37-14	43	40-8	43	31-5	31	63-14	55	2.00	......
1913	87-11	121	26-10	45	15-2	22	15-4	20	10-8	13	10-12	12	2-15	3	6-8	6	2.00	......
1914	239-13	298	58-7	88	41-2	54	32-9	40	44-6	53	28-7	30	14-14	15	20-0	18	2.67	......
1915	180-5	196	43-10	60	21-14	26	26-14	29	21-10	22	22-12	22	16-12	15	26-13	22	4.33	......
Average	200.9	230	41.9	63	26.5	33	26.2	31	27.6	31	25.8	26	18.4	18	34.6	29	2.28	......
Standard grade—																		
1910	114-11	124	17-11	26	12-12	16	15-11	18	14-15	16	20-4	20	9-12	9	23-10	19	0	......
1911	189-7	239	90-15	131	35-3	42	32-1	35	15-2	16	7-0	7	3-5	3	5-13	5	1.80	......
1912	127-11	168	47-11	79	15-14	21	18-0	22	13-7	15	10-4	11	5-1	5	17-6	15	2.17	......
1913	204-10	330	106-2	200	34-11	51	26-0	35	20-14	26	8-1	9	6-12	7	2-2	2	.67	......
1914	122-10	165	51-4	82	19-13	26	15-10	19	14-1	16	10-6	11	5-0	5	6-8	6	3.00	......
1915	32-4	38	12-3	17	3-6	4	1-14	2	5-6	6	5-1	5	3-4	3	1-2	1	2.00	......
Average	131.9	177	54.3	89	20.3	27	18.2	22	14.0	16	10.2	11	5.5	5	9.4	8	1.61	......
Cull fruits—																		
1912	5-9	13	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1913	39-12	97	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1914	10-6	21	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.67	......
1915	4-4	7	......	......	......	......	......	......	......	......	......	......	......	......	......	......	2.00	......
Average	15.0	35	......	......	......	......	......	......	......	......	......	......	......	......	......	......	3.34	......

Total crop—																		
1910	323– 4	331	41– 7	61	20–10	26	36– 6	42	38– 7	41	51– 2	50	40– 8	37	94–12	74	0	......
1911	418– 1	501	156–11	224	81– 0	94	67– 7	75	42–15	45	28– 7	28	16–12	15	24–13	20	2.13	......
1912	393–12	475	80–15	132	43– 0	57	44– 9	55	51– 5	58	50–12	54	36– 6	36	81– 4	70	2.11	0
1913	332– 1	548	132–12	245	49–13	73	41– 4	55	31– 6	39	18–13	21	9–11	10	8–10	8	1.33	0
1914	372–13	484	109–11	170	60–15	80	48– 3	59	58– 7	69	38–13	41	19–14	20	26– 8	24	3.44	4
1915	216–13	241	55–13	77	25– 4	30	28–12	31	27– 0	28	27–13	27	20– 0	18	27–15	23	3.00	3
Average	**342.8**	**430**	**96.2**	**152**	**46.8**	**60**	**44.4**	**53**	**41.6**	**47**	**36.0**	**37**	**23.9**	**23**	**44.0**	**37**	**2.00**	**1.75**
18. Tree No. 1-16-33 Marsh strain: Ivory-White grade—																		
1910	213–11	157	0– 0	0	0– 0	0	0–14	1	2–15	3	13– 7	13	13– 0	12	183– 7	128	0	......
1911	329– 9	351	38–13	55	35– 0	44	56–13	66	48–11	51	42–12	43	43–12	41	63–12	51	2.00	......
1912	200– 7	206	9– 0	13	12–12	17	22– 8	26	28– 0	32	26–12	28	23– 0	23	78– 7	67	.33	......
1913	12–14	16	2–13	5	4–12	4	2–12	4	1–11	2	0–14	1	0– 0	0	0– 0	0	3.50	......
1914	231– 9	285	44–14	72	36–14	50	39– 0	48	42– 0	48	30– 9	32	19–14	19	18– 6	16	4.00	......
1915	43–10	45	6–12	10	3– 4	4	9– 0	10	4– 0	4	3– 2	3	4– 8	4	13– 0	10	4.33	......
Average	172.0	177	17.1	26	15.4	20	21.8	26	21.2	26	19.6	20	17.3	17	59.5	45	2.36	......
Standard grade—																		
1910	126– 1	99	2–12	4	2– 8	3	0–14	1	2– 0	2	7– 3	7	12– 0	11	98–12	71	1.67	......
1911	249–10	287	52– 0	76	49– 5	61	52–15	59	33– 6	35	20– 5	20	17– 6	16	24– 5	20	3.17	......
1912	172– 6	196	21– 0	34	11–12	16	27–10	33	19–12	22	29– 8	30	22–15	22	39–13	39	1.17	......
1913	192–10	355	124–13	264	31– 5	46	13–13	18	18– 2	22	3– 8	4	1– 1	1	0– 0	0	2.00	......
1914	114–13	146	29–11	49	16– 2	22	16– 2	20	20– 6	23	14– 6	15	10– 4	10	7–14	7	1.00	......
1915	21–14	18	1– 8	2	0– 0	0	1–12	2	2– 0	2	3– 6	3	2– 4	2	11– 0	7	3.00	......
Average	146.2	184	38.6	71	18.5	25	18.9	22	15.9	18	13.0	13	11.0	10	30.3	24	2.00	......
Cull fruits—																		
1912	6– 0	11	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1913	82– 5	237	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1914	11– 1	24	......	......	......	......	......	......	......	......	......	......	......	......	......	......	2.67	......
1915	13– 4	14	......	......	......	......	......	......	......	......	......	......	......	......	......	......	5.67	......
Average	28.2	72	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.17	......
Total crop—																		
1910	339–12	256	2–12	4	2– 8	3	1–12	2	4–15	5	20–10	20	25– 0	23	282– 3	199	1.25	......
1911	579– 3	638	90–13	131	84– 5	105	109–12	125	82– 1	86	63– 1	63	61– 2	57	88– 1	71	2.78	......
1912	378–13	413	30– 0	47	24– 8	33	50– 2	59	47–12	54	56– 4	58	45–15	45	118– 4	106	.89	0
1913	287–13	608	127–10	269	36– 1	50	16– 9	22	19–13	24	4– 6	5	1– 1	1	0– 0	0	2.75	0
1914	357– 7	455	74– 9	121	53– 0	72	55– 2	68	62– 6	71	44–15	47	30– 2	29	26– 4	23	2.56	5
1915	78–12	77	8– 4	12	3– 4	4	10–12	12	6– 0	6	6– 8	6	6–12	6	24– 0	17	4.33	0
Average	**337.0**	**408**	**55.7**	**97**	**33.9**	**45**	**40.7**	**48**	**37.2**	**41**	**32.6**	**33**	**28.3**	**27**	**89.8**	**69**	**2.43**	**1.25**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT A, PLANTED IN 1898—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
19. Tree No. 1-15-32, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	177- 2	204	47- 4	69	16- 0	20	30- 9	36	22- 6	24	19- 3	19	14- 1	13	27-11	23	0	....
1911	148- 2	186	77- 5	112	12- 6	15	13-15	16	18- 3	19	13- 9	13	3- 6	3	9- 6	8	1.33	....
1912	276- 0	367	79- 9	130	47- 8	65	48- 0	61	47- 5	56	24- 9	27	15- 1	15	14- 0	13	1.33	....
1913	50- 2	70	12- 7	23	7- 8	11	8- 1	11	6-10	8	7-14	9	5-11	6	1-15	2	.33	....
1914	57- 6	77	23-15	37	11- 4	15	7- 5	9	7- 1	8	5-11	6	1- 0	1	1- 2	1	5.33	....
1915	112-12	150	69- 1	103	6-11	8	13- 4	15	10- 8	11	10- 0	10	2- 2	2	1- 2	1	2.67	....
Average	136.9	176	51.6	79	16.9	22	20.2	25	18.7	21	13.5	14	6.9	7	9.2	8	1.83	....
Standard grade—																		
1910	118-13	145	33- 4	54	16- 4	21	19-14	23	12-14	14	10- 1	10	14- 4	13	12- 4	10	.50	....
1911	139- 9	190	84-14	132	11- 0	12	22- 6	25	8- 8	9	8- 9	8	2- 2	2	2- 2	2	4.00	....
1912	150- 3	214	74-11	122	30- 1	40	17- 0	21	14- 0	16	7- 7	8	5-14	6	1- 2	1	2.40	....
1913	137- 0	266	110-12	229	15- 5	23	3-10	5	4-12	6	2- 9	3	0- 0	0	0- 0	0	2.00	....
1914	141-10	204	77- 8	128	23- 2	30	14-12	18	13- 8	15	7- 8	8	4- 2	4	1- 2	1	5.00	....
1915	133- 7	182	83- 8	125	19-10	24	17- 7	20	7-11	8	1-14	2	2- 3	2	1- 2	1	5.00	....
Average	136.8	200	77.4	132	19.2	25	15.8	18	10.2	11	6.3	7	4.7	4	3.0	3	3.15	....
Cull fruits—																		
1912	1- 2	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	50- 4	133	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	23-12	60	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.67	....
1915	19- 8	38	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.00	....
Average	23.6	59	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.84	....

otal crop—																		
1910	295-15	349	80- 8	123	32- 4	41	50- 7	59	35- 4	38	29- 4	29	28- 5	26	39-15	33	.33	....
1911	287-11	376	162- 3	244	23- 6	27	36- 5	41	26-11	28	22- 2	21	5- 8	5	11- 8	10	2.86	....
1912	427- 5	586	154- 4	252	77- 9	105	65- 0	82	61- 5	72	32- 0	35	20-15	21	15- 2	14	2.00	0
1913	237- 6	469	123- 3	252	22-13	34	11-11	16	11- 6	14	10- 7	12	5-11	6	1-15	2	1.00	0
1914	222-12	341	101- 7	165	34- 6	45	22- 1	27	20- 9	23	13- 3	14	5- 2	5	2- 4	2	4.33	5
1915	265-11	370	152- 9	228	26- 5	32	30-11	35	18- 3	19	11-14	12	4- 5	4	2- 4	2	3.63	5
Average	**289.5**	**415**	**129.0**	**211**	**36.1**	**47**	**36.0**	**43**	**28.9**	**32**	**19.8**	**21**	**11.6**	**11**	**12.2**	**11**	**2.36**	**2.50**
20. Tree No. 1-18-33, Marsh strain:																		
Ivory-White grade—																		
1910	188- 3	150	5-12	8	4- 0	5	6- 2	7	9- 9	10	9- 2	9	11- 0	10	142-10	101	0	....
1911	383-12	445	110- 1	155	71-10	87	62-14	71	55- 0	56	38-10	37	24- 1	22	21- 8	17	1.33	....
1912	20-10	25	4-13	8	2- 8	3	3- 4	4	0-14	1	3-14	4	4- 4	4	1- 1	1	5.00	....
1913	37-14	61	15- 1	29	8- 3	13	5- 9	8	3-14	5	2- 7	3	1-12	2	1- 0	1	0	....
1914	215-15	273	94-11	127	31- 0	42	34-10	44	23- 2	27	20- 0	21	8- 1	8	4- 7	4	4.00	....
1915	125- 8	149	46- 2	68	7- 4	9	18- 4	21	20- 4	21	11- 6	11	12- 6	11	9-14	8	4.00	....
Average	162.0	184	46.1	66	20.8	27	21.8	26	18.8	20	14.2	14	10.2	9	30.1	22	2.39	....
Standard grade—																		
1910	138-14	123	6- 8	10	7- 2	9	14-14	17	6-10	7	8-14	9	18- 3	17	76-11	54	1.00	....
1911	90- 3	115	37-13	56	22- 2	27	18-14	21	4-12	5	2- 0	2	2- 3	2	2- 7	2	1.33	....
1912	13- 9	14	2-11	4	0- 0	0	1-12	2	0-14	1	2-14	3	0- 0	0	5- 6	4	3.20	....
1913	138-11	258	95- 9	196	21- 2	33	13- 8	19	3- 2	4	2- 9	3	1-13	2	1- 0	1	0	....
1914	86- 3	134	45-12	83	13-11	19	16-14	21	5- 2	6	4-12	5	0- 0	0	0- 0	0	3.00	....
1915	29- 9	37	10- 1	16	1-10	2	7-12	9	6- 8	7	1- 1	1	1- 2	1	1- 7	1	4.67	....
Average	82.8	114	33.0	61	10.9	15	12.3	15	4.5	5	3.7	4	3.9	4	14.5	10	2.20	....
Cull fruits—																		
1912	0- 0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	132- 3	384	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	22- 0	49	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.67	....
1915	11- 2	21	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.00	....
Average	41.3	113	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.36	....
Total crop—																		
1910	327- 1	273	12- 4	18	11- 2	14	21- 0	24	16- 3	17	18- 0	18	29- 3	27	219- 5	155	.67	....
1911	473-15	560	147-14	211	93-12	114	81-12	92	59-12	61	40-10	39	26- 4	24	23-15	19	1.56	....
1912	34- 3	39	7- 8	12	2- 8	3	5- 0	6	1-12	2	6-12	7	4- 4	4	6- 7	5	3.44	0
1913	308-12	703	110-10	225	29- 5	46	19- 1	27	7- 0	9	5- 0	6	3- 9	4	2- 0	2	0	0
1914	324- 2	456	140- 7	210	44-11	61	51- 8	65	28- 4	33	24-12	26	8- 1	8	4- 7	4	4.22	4
1915	166- 3	207	56- 3	84	8-14	11	26- 0	30	26-12	28	12- 7	12	13- 8	12	11- 5	9	4.22	2
Average	**272.4**	**373**	**79.1**	**127**	**31.7**	**42**	**34.1**	**41**	**23.3**	**25**	**17.9**	**18**	**14.1**	**13**	**44.6**	**32**	**2.35**	**1.50**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT A, PLANTED IN 1898—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																		Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
21. Tree No. 1-14-29, Rough Seedy strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	14- 4	9	0- 0	0	0- 0	0	0- 0	0	0- 0	0	0- 0	0	0- 0	0	14- 4	9	54.00	....
1911	100-10	107	21- 4	28	11- 3	13	11-13	13	22-10	23	10-11	10	11- 4	10	11-13	10	52.00	....
1912	19- 2	15	0- 0	0	0- 0	0	0-14	1	0-15	1	3- 2	3	2- 3	2	12- 0	8	66.00	....
1913	84- 3	135	43- 0	78	14- 4	22	11-15	17	10- 2	13	2-12	3	1- 2	1	1- 0	1	37.33	....
1914	83- 6	87	5-13	9	5- 1	7	7- 3	9	13-15	16	7- 9	8	12- 6	12	31- 7	26	47.33	....
1915	35- 2	37	8-11	11	2-11	3	7- 9	8	7- 0	7	5- 7	5	1- 2	1	2-10	2	62.33	....
Average	56.1	65	13.1	21	5.5	8	6.6	8	9.1	10	4.9	5	4.7	4	12.2	9	53.17	....
Standard grade—																		
1910	41-10	26	0- 0	0	0- 0	0	0- 0	0	0- 0	0	1- 0	1	1- 1	1	39-9	24	49.50	....
1911	379-11	444	152- 9	205	67- 0	77	57- 2	61	47-11	50	29-12	29	12- 0	11	13-9	11	50.40	....
1912	75- 9	51	0-11	1	0-13	1	4- 2	5	1-15	2	3- 2	3	2- 4	2	62-10	37	51.40	....
1913	186- 0	308	112- 2	206	42- 7	62	16- 8	22	10- 6	13	0-13	1	3-12	4	0-0	0	43.00	....
1914	181-13	124	9-14	16	11-13	15	4- 4	5	18-10	21	21- 3	22	22-0	21	94-1	24	52.67	....
1915	113- 4	109	11-14	16	7- 3	8	14-15	16	18- 2	18	19-10	18	16-6	14	25-2	19	61.33	....
Average	163.0	177	47.9	74	21.6	27	16.1	18	16.1	17	12.6	12	9.6	9	39.1	19	51.38	....
Cull fruits—																		
1912	4-11	6	....	......	....	......	....	......	....	......	....	......	....	......	....	......		....
1913	86- 8	175	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1914	16- 6	7	....	......	....	......	....	......	....	......	....	......	....	......	....	......	45.50	....
1915	72-13	85	....	......	....	......	....	......	....	......	....	......	....	......	....	......	57.67	....
Average	45.1	68	....	......	....	......	....	......	....	......	....	......	....	......	....	......	51.59	....

Total crop—																		
1910	55-14	35	0- 0	0	0- 0	0	0-0	0	0- 0	0	1- 0	1	1- 1	1	53-13	33	51.00	....
1911	480- 5	551	173-13	233	78- 3	90	68-15	74	70- 5	73	40- 7	39	23- 4	21	25- 6	21	51.00	....
1912	99- 6	72	0-11	1	0-13	1	5-0	6	2-14	3	6- 4	6	4- 7	4	74-10	45	55.77	0
1913	356-11	618	155- 2	284	56-11	84	28-7	39	20- 8	26	3- 9	4	4-14	4	1- 0	1	39.60	0
1914	281- 9	218	15-11	25	16-14	22	11-7	14	32- 9	37	28-12	30	34- 6	33	125- 8	50	48.63	2
1915	221- 3	231	20- 9	27	9-14	11	22-8	24	25- 2	25	25- 1	23	17- 8	15	27-12	21	60.44	5
Average	**249.2**	**288**	**61.0**	**95**	**27.1**	**35**	**22.7**	**26**	**25.2**	**27**	**17.5**	**17**	**14.3**	**13**	**51.3**	**29**	**51.07**	**1.75**
22. Tree No. 1-14-31, Rough Seedy strain:																		
Ivory-White grade—																		
1910	14- 7	14	2-10	4	1- 8	2	1- 9	2	1-12	2	0- 0	0	0- 0	0	7- 0	4	50.00	....
1911	108- 0	109	17-15	24	14-12	17	10- 4	11	5- 0	5	15- 8	15	17- 9	16	27- 0	21	54.67	....
1912	21-15	17	0-11	1	0- 0	0	0- 0	0	0- 0	0	2- 2	2	5- 4	5	13-14	9	55.00	....
1913	121-14	200	59- 5	112	32-14	49	13-13	19	13- 6	17	0-12	1	1-12	2	0- 0	0	45.50	....
1914	35- 1	34	2- 2	3	3- 0	4	1-10	2	3-10	4	3- 0	3	5- 5	5	16- 6	13	58.33	....
1915	35- 8	39	11- 0	14	5- 6	6	5-10	6	8- 0	8	2- 2	2	2- 4	2	1- 2	1	57.00	....
Average	56.1	69	15.6	27	9.6	13	5.5	7	5.3	6	3.9	4	5.4	5	10.9	8	53.42	....
Standard grade—																		
1910	20- 3	13	0- 0	0	0- 0	0	0- 0	0	0- 0	0	0- 0	0	2- 4	2	17-15	11	62.00	....
1911	309- 9	339	80- 2	111	41- 2	47	40- 9	43	46-12	47	33- 5	32	28- 9	26	39- 2	33	47.17	....
1912	144-11	96	0-12	1	0- 0	0	3- 8	4	1- 0	1	5- 4	5	5- 9	5	128-10	80	29.00	....
1913	118- 0	221	88- 7	179	19- 0	28	6- 9	9	4- 0	5	0- 0	0	0- 0	0	0- 0	0	40.00	....
1914	169-11	157	6- 2	10	4- 7	6	4- 6	5	20- 1	22	24- 5	25	19- 3	18	91- 3	71	48.00	....
1915	205- 1	219	43- 8	61	18- 8	21	36- 3	39	37- 6	37	31- 2	29	14- 8	13	23-14	19	53.33	....
Average	161.2	174	36.5	60	13.8	17	15.2	16	18.2	19	15.7	15	11.6	11	50.1	36	46.58	....
Cull fruits—																		
1912	0-14	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	58- 3	134	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	3- 6	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	51.33	....
1915	30- 7	43	....	....	....	....	....	....	....	....	....	....	....	....	....	....	56.00	....
Average	23.2	46	....	....	....	....	....	....	....	....	....	....	....	....	....	....	53.67	....
Total crop—																		
1910	34-10	27	2-10	4	1- 8	2	1- 9	2	1-12	2	0- 0	0	2- 4	2	24-15	15	58.00	....
1911	417- 9	448	98- 1	135	55-14	64	50-13	54	51-12	52	48-13	47	46- 2	42	66- 2	54	49.67	....
1912	167- 8	114	1- 7	2	0- 0	0	3- 8	4	1- 0	1	7- 6	7	10-13	10	142- 8	89	38.75	0
1913	298- 1	555	147-12	291	51-14	77	20- 6	28	17- 6	22	0-12	1	1-12	2	0- 0	0	42.75	0
1914	208- 2	196	8- 4	13	7- 7	10	6- 0	7	23-11	26	27- 5	28	24- 8	23	107- 9	84	52.56	2
1915	271- 0	301	54- 8	75	23-14	27	41-13	45	45- 6	45	33- 4	31	16-12	16	25- 0	20	55.44	9
Average	**232.8**	**274**	**52.1**	**87**	**23.4**	**30**	**20.7**	**23**	**23.5**	**25**	**19.6**	**19**	**17.0**	**16**	**61.0**	**44**	**49.53**	**2.75**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT A, PLANTED IN 1898—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
23. Tree No. 1-18-31, Smooth Seedy strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	11- 7	6	0- 0	0	0- 0	0	0- 0	0	0- 0	0	0- 0	0	0- 0	0	11- 7	6	42.00	....
1911	322- 0	316	11- 3	15	27-11	33	59- 0	63	52- 2	53	61-15	56	61-12	56	48- 5	40	46.33	....
1912	14- 8	14	2-10	4	0- 0	0	1-10	2	0- 0	0	0- 3	1	2- 3	2	7-14	5	61.33	....
1913	40- 5	60	9- 7	17	9-11	15	9- 2	13	6-10	9	1-11	2	0-13	1	2-15	3	31.67	....
1914	210- 9	223	7-14	12	20-15	27	31-15	38	40- 0	44	29- 9	30	35-11	34	44- 9	38	50.67	....
1915	59- 2	45	0- 0	0	0- 0	0	0-14	1	0- 0	0	9-10	9	5-14	5	42-12	30	56.00	....
Average	109.7	111	5.2	8	9.7	12	17.1	20	16.4	18	17.2	16	17.7	16	26.3	20	48.00	....
Standard grade—																		
1910	31- 8	17	0- 0	0	0- 0	0	0- 0	0	0- 0	0	0- 0	0	0- 0	0	31- 8	17	43.00	....
1911	166-12	171	11-13	16	15-12	18	37-15	40	28-12	29	35- 1	35	20-13	19	16-10	14	45.60	....
1912	41- 7	27	1- 3	2	0- 0	0	0- 0	0	0- 0	0	0-15	1	1- 2	1	38- 3	23	46.60	....
1913	176- 1	256	46-10	87	37- 9	57	16- 4	23	29-14	39	16- 3	20	19- 9	21	9- 6	9	45.67	....
1914	122-13	132	14-12	23	10-13	14	18- 6	22	18-10	20	9- 9	10	11- 9	11	39- 2	32	50.00	....
1915	31- 6	24	0- 0	0	0- 0	0	0-12	1	0- 0	0	3- 2	3	4- 8	4	23- 0	16	63.00	....
Average	95.0	105	12.4	21	10.7	15	12.2	14	12.9	14	10.8	12	9.6	10	26.3	19	48.98	....
Cull fruits—																		
1912	0- 0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	89- 0	168	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	5- 8	10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	50.00	....
1915	11-12	17	....	....	....	....	....	....	....	....	....	....	....	....	....	....	57.00	....
Average	26.6	48	....	....	....	....	....	....	....	....	....	....	....	....	....	....	53.50	....

Total crop—																	
1910	42–15	23	0– 0	0	0– 0	0	0– 0	0	0– 0	0	0– 0	0	0– 0	0	12–15	23	42.67	....
1911	488–12	487	23– 0	31	43– 7	51	96–15	103	80–14	82	97– 0	91	82– 9	75	64–15	54	45.88	....
1912	55–15	41	3–13	6	0– 0	0	1–10	2	0– 0	0	1– 2	2	3– 5	3	46– 1	28	52.13	0
1913	305–6	484	56– 1	104	47– 4	72	25– 6	36	36– 8	48	18– 8	22	20– 6	22	12– 5	12	38.67	0
1914	338–14	365	22–10	35	31–12	41	50– 5	60	58–10	64	39– 2	40	47– 4	45	83–11	70	50.22	1
1915	102– 4	86	0– 0	0	0– 0	0	1–10	2	0– 0	0	12–12	12	10– 6	9	65–12	46	58.67	1
Average	**222.4**	**248**	**17.6**	**29**	**20.4**	**27**	**29.3**	**34**	**29.3**	**32**	**28.1**	**28**	**27.3**	**26**	**52.6**	**39**	**48.04**	**0.5**
24. Tree No. 1-15-33, Rough Seedy strain: Ivory-White grade—																	
1910	7– 9	5	0– 0	0	0– 0	0	0– 0	0	0– 0	0	0– 0	0	1– 3	1	6– 6	4	90.00	....
1911	257–11	268	34– 4	44	33– 1	38	35– 2	38	68–11	70	26–15	26	32–13	30	26–13	22	61.00	....
1912	0– 0	0	0– 0	0	0– 0	0	0– 0	0	0– 0	0	0– 0	0	0– 0	0	0– 0	0	0	....
1913	20– 1	32	9–12	18	3– 6	5	3–12	5	2– 5	3	0–14	1	0– 0	0	0– 0	0	49.50	....
1914	35– 1	34	1– 4	2	0–12	1	1–12	2	8– 4	9	5–15	6	0– 0	0	17– 2	14	55.00	....
1915	16–11	18	3– 1	5	0– 0	0	0– 0	0	2–13	3	5– 5	5	4– 6	4	1– 2	1	60.00	....
Average	56.2	60	8.0	11	6.2	7	6.8	8	13.7	14	6.5	6	6.4	6	8.6	7	52.58	....
Standard grade—																	
1910	29– 7	15	0– 0	0	0– 0	0	0–13	1	0– 0	0	0– 0	0	0– 0	0	28–10	14	63.00	....
1911	270– 6	301	78–11	106	47–12	54	52–15	55	30–15	31	30– 2	29	18–10	17	11– 5	9	52.50	....
1912	64– 1	40	0– 0	0	0– 0	0	0– 0	0	2– 3	2	0– 0	0	0– 0	0	61–14	38	66.50	....
1913	116–14	229	102– 3	195	4– 7	21	4– 8	6	4– 0	5	1–12	2	0– 0	0	0– 0	0	37.50	....
1914	139–11	118	5–10	8	3–14	5	6– 0	7	8– 6	9	12– 0	12	24– 4	23	79– 9	54	44.00	....
1915	78– 6	75	9– 9	13	5–13	7	8– 8	9	7–12	8	6– 4	6	11– 6	10	29– 2	22	60.00	....
Average	116.5	130	32.7	54	10.3	15	12.1	13	8.9	9	8.4	8	9.0	8	35.1	23	53.92	....
Cull fruits—																	
1912	6– 2	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	134–10	342	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	44– 1	39	....	....	....	....	....	....	....	....	....	....	....	....	....	....	54.00	....
1915	68–12	81	....	....	....	....	....	....	....	....	....	....	....	....	....	....	64.67	....
Average	63.4	117	....	....	....	....	....	....	....	....	....	....	....	....	....	....	59.34	....
Total crop—																	
1910	37– 0	20	0– 0	0	0– 0	0	0–13	1	0– 0	0	0– 0	0	1– 3	1	35– 0	18	72.00	....
1911	528– 1	569	112–15	150	80–13	92	88– 1	93	99–10	101	57– 1	55	51– 7	47	38– 2	31	55.33	....
1912	70– 3	45	0– 0	0	0– 0	0	0– 0	0	2– 3	2	0– 0	0	0– 0	0	61–14	38	66.50	0
1913	271– 9	603	111–15	213	7–13	26	8– 4	11	6– 5	8	2–10	3	0– 0	0	0– 0	0	43.50	0
1914	218–13	191	6–14	10	4–10	6	7–12	9	16–10	18	17–15	18	24– 4	23	96–11	68	51.00	1
1915	163–13	174	12–10	18	5–13	7	8– 8	9	10– 9	11	11– 9	11	15–12	14	30– 4	23	61.56	7
Average	**214.9**	**267**	**40.7**	**65**	**16.5**	**22**	**18.9**	**21**	**22.6**	**23**	**14.9**	**14**	**15.4**	**14**	**43.7**	**30**	**58.32**	**2.0**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT A, PLANTED IN 1898—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
25. Tree No. 1-15-29, Rough seedy strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	22–12	18	0– 0	0	0– 0	0	0–14	1	1–14	2	1– 0	1	2– 1	2	16–15	12	57.00	....
1911	137– 2	152	39– 7	53	23–10	27	19– 5	21	16–13	17	18–14	18	5–11	5	13– 6	11	50.00	....
1912	21– 9	20	0–11	1	0– 0	0	0– 0	0	3–14	4	1–14	2	3– 2	3	12– 0	10	60.67	....
1913	24– 9	40	13– 6	25	5– 7	8	2– 4	3	0–14	1	2–10	3	0– 0	0	0– 0	0	36.00	....
1914	88– 4	95	6– 5	9	9– 8	12	15–15	19	18– 2	20	17– 5	17	7–11	7	13– 6	11	60.33	....
1915	44–10	43	6–10	9	2– 8	3	8– 8	9	7– 6	7	2– 1	2	3– 7	3	14– 2	10	56.00	....
Average	56.5	61	11.1	16	6.8	8	7.8	9	8.1	9	7.3	7	3.7	3	11.6	9	53.33	....
Standard grade—																		
1910	3– 6	2	0– 0	0	0– 0	0	0– 0	0	0– 0	0	0– 0	0	0– 0	0	3– 6	2	49.50	....
1911	219–10	244	59– 1	81	34– 1	38	40– 3	43	32–15	33	28–11	27	17–13	16	6–14	6	48.75	....
1912	133– 7	109	0–11	1	3– 4	4	9–11	11	7–10	8	6–15	7	16– 9	15	88–11	63	45.80	....
1913	160– 0	267	99–10	184	33–13	50	12– 2	16	9– 1	11	3– 8	4	1–14	2	0– 0	0	41.50	....
1914	122– 5	132	13–11	20	9– 6	12	11– 4	13	14–12	16	12– 2	12	14–14	14	46– 4	45	40.00	....
1915	113– 7	101	9–14	13	6–14	8	11– 6	12	7– 5	7	15– 4	14	9–10	8	53– 2	39	58.33	....
Average	125.4	143	30.5	50	14.6	19	14.1	16	12.0	12	11.1	11	10.1	9	33.1	26	47.31	....
Cull fruits—																		
1912	3– 5	4	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1913	53– 8	116	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1914	1– 7	3	....	......	....	......	....	......	....	......	....	......	....	......	....	......	58.00	....
1915	25–10	33	....	......	....	......	....	......	....	......	....	......	....	......	....	......	54.67	....
Average	21.0	39	....	......	....	......	....	......	....	......	....	......	....	......	....	......	56.35	....

Total crop—																	
1910	26–2	20	0–0	0	0–0	0	0–14	1	1–14	2	1–0	1	2–1	2	20–5	14	52.00	....
1911	356–12	396	98–8	134	57–11	65	59–8	64	49–12	50	47–9	45	23–8	21	20–4	17	49.28	....
1912	158–5	133	1–6	2	3–4	4	9–11	11	11–8	12	8–13	9	19–11	18	100–11	73	51.38	0
1913	238–1	423	113–0	209	39–4	58	14–6	19	9–15	12	6–2	7	1–14	2	0–0	0	38.75	2
1914	212–0	230	20–0	29	18–14	24	27–3	32	32–14	36	29–7	29	22–9	21	59–10	56	51.28	2
1915	183–11	177	16–8	22	9–6	11	19–14	21	14–11	14	17–5	16	13–1	11	67–4	49	56.33	4
Average	**195.8**	**230**	**41.6**	**66**	**21.4**	**27**	**21.9**	**25**	**20.1**	**21**	**18.4**	**18**	**13.8**	**12**	**44.7**	**35**	**49.84**	**2.0**

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903.

1. Tree No. 23–59–13, Marsh strain:																	
Ivory-White grade—																	
1910	171–6	219	54–13	82	25–2	33	34–6	42	28–0	32	12–13	14	5–5	6	10–15	10	....	....
1911	221–3	178	2–9	4	2–8	3	3–7	4	4–7	5	11–1	11	31–9	28	165–10	123	....	....
1912	212–7	273	54–1	87	33–15	46	43–6	54	28–11	33	26–5	28	12–15	13	13–2	12	1.67	....
1913	143–0	165	14–1	23	26–0	33	23–12	28	32–12	36	22–12	23	15–13	15	7–14	7	1.67	....
1914	77–12	109	43–12	68	14–11	19	12–10	15	3–10	4	2–1	2	1–0	1	0–0	0	5.67	....
1915	128–15	158	49–14	74	20–0	25	25–11	28	10–14	11	9–11	9	8–0	7	4–13	4	2.33	....
Average	159.1	184	36.5	56	20.4	27	23.9	29	18.1	20	14.1	15	12.4	11	33.8	26	2.84	....
Standard grade—																	
1910	80–12	110	26–5	42	9–0	12	20–6	26	16–9	20	6–8	8	2–0	2	0–0	0	....	....
1911	63–12	61	3–5	7	2–6	3	5–10	6	7–15	8	4–13	5	11–2	10	28–9	22	....	....
1912	108–7	139	32–15	52	17–10	23	19–15	24	16–0	18	12–5	13	2–15	3	6–11	6	3.00	....
1913	60–3	80	18–3	33	12–12	16	6–0	7	15–11	17	2–1	2	4–6	4	1–2	1	1.33	....
1914	51–11	82	35–2	61	10–10	14	3–5	4	1–12	2	0–14	1	0–0	0	0–0	0	4.33	....
1915	63–2	77	21–3	34	8–12	10	12–2	13	6–0	6	10–7	10	3–7	3	1–3	1	5.67	....
Average	71.3	92	22.8	38	10.2	13	11.2	13	10.7	12	6.2	6	4.0	4	6.2	5	3.58	....
Cull fruits—																	
1912	8–4	13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	13–8	52	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	18–12	41	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.00	....
1915	17–7	34	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.00	....
Average	14.5	35	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.00	....
Total crop—																	
1910	252–2	329	81–2	124	34–2	45	54–12	68	44–9	52	19–5	22	7–5	8	10–15	10	....	....
1911	284–15	239	5–14	11	4–14	6	9–1	10	12–6	13	15–14	16	42–11	38	194–3	145	....	....
1912	329–2	425	87–0	139	51–9	69	63–5	78	44–11	51	38–10	41	15–14	16	19–13	18	2.56	1
1913	216–11	297	32–4	56	38–12	49	29–12	35	48–7	53	24–13	25	20–3	19	9–0	8	1.50	0
1914	148–3	232	78–14	128	25–5	33	15–15	19	5–6	6	2–15	3	1–0	1	0–0	0	4.33	2
1915	209–8	269	71–1	108	28–12	35	37–13	41	16–14	17	20–2	14	11–7	10	6–0	5	4.33	1
Average	**240.1**	**299**	**59.3**	**94**	**30.6**	**40**	**35.1**	**42**	**28.7**	**32**	**20.3**	**21**	**16.4**	**15**	**40.0**	**31**	**3.18**	**1.00**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
2. Tree No. 23-59-5, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	172- 1	223	55- 5	84	26- 0	35	33- 5	41	25-13	30	16- 6	18	7-13	8	7- 7	7	......	......
1911	184-14	159	4- 2	6	2- 8	3	7- 2	8	8-10	9	18- 2	18	18- 2	17	126- 4	98	......	......
1912	159-12	184	14- 8	23	13- 5	18	29-11	37	18-11	22	24- 1	26	31- 9	32	27-15	26	1.33	......
1913	154-15	168	7-15	12	11- 0	14	18- 2	22	36- 8	41	34-15	36	22- 4	22	24- 3	21	0	......
1914	80- 5	102	29-15	45	15- 0	19	14-10	17	12- 4	13	5- 2	5	3- 6	3	0- 0	0	6.00	......
1915	88- 5	98	11- 0	15	9-14	12	22- 0	25	15-14	19	16- 5	16	5-10	5	7-10	6	5.00	
Average	140.0	156	20.6	31	12.9	17	20.8	25	19.6	22	19.2	20	14.8	15	32.2	27	3.08	......
Standard grade—																		
1910	44- 6	64	20- 5	33	5-12	8	9-14	13	3-14	5	1-11	2	0-14	1	2- 0	2	......	......
1911	73-10	73	6- 6	9	2- 7	3	8- 0	9	7-10	8	13- 5	13	18-10	17	17- 4	14	......	......
1912	102- 7	124	19- 8	30	12- 1	16	21- 8	26	17-12	20	12-15	14	10- 2	10	8- 9	8	2.33	......
1913	68- 4	81	13- 4	20	8- 2	10	14- 7	17	17-11	20	6-13	7	3- 1	3	4-14	4	2.67	......
1914	110-13	149	48-12	75	32- 6	41	15- 4	18	10- 4	11	2- 2	2	2- 1	2	0- 0	0	3.67	......
1915	59-10	64	9-10	13	8- 8	10	13- 5	14	13-10	14	7- 6	7	3- 7	3	3-12	3	3.67	......
Average	76.5	93	19.5	30	11.1	15	13.7	16	11.9	13	7.3	7	6.3	6	6.1	5	3.08	......
Cull fruits—																		
1912	7-10	11	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1913	11- 8	39	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1914	17-13	30	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.33	......
1915	5-14	9	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.33	......
Average	10.7	22	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.33	......

Total crop—																		
1910	216- 7	287	75-10	117	31-12	43	43- 3	54	29-11	35	18- 1	20	8-11	9	9- 7	9	....	....
1911	258- 8	232	10- 8	15	4-15	6	15- 2	17	16-14	17	31- 7	31	36-12	34	143- 8	112	....	....
1912	269-13	319	34- 0	53	25- 6	34	51- 3	63	36- 7	42	37- 0	40	41-11	42	36- 8	34	2.00	0
1913	234-11	288	21- 3	32	19- 2	24	32- 9	39	54- 3	61	41-12	43	25- 5	25	29- 1	25	1.33	2
1914	208-15	281	78-11	120	47- 6	60	29-14	35	22- 8	24	7- 4	7	5- 7	5	0- 0	0	4.67	7
1915	153-13	171	20-10	28	18- 6	22	35- 5	39	29- 8	33	23-11	23	9- 1	8	11- 6	9	4.33	4
Average	**223.7**	**263**	**40.1**	**61**	**24.5**	**32**	**34.5**	**41**	**31.5**	**35**	**26.5**	**27**	**21.1**	**21**	**38.3**	**32**	**3.08**	**3.25**
3. Tree No. 23-59-11, Marsh strain:																		
Ivory-White grade—																		
1910	132- 2	167	29- 6	46	12- 5	17	19-10	25	33- 9	39	17- 0	19	11- 4	12	9- 0	9	....	....
1911	159- 8	117	1-11	3	0-12	1	2- 9	3	3- 0	3	4- 4	4	5-10	5	141-10	98	....	....
1912	211- 7	300	86- 1	135	24- 1	47	44- 8	56	24- 4	28	19- 8	21	9-12	10	3- 5	3	3.00	....
1913	175-10	175	7- 1	11	7-14	10	10- 1	12	26-10	29	28- 7	29	33-13	32	61-12	52	.33	....
1914	88-13	119	39-12	60	16- 4	21	16- 7	20	12- 9	14	2-12	3	1- 1	1	0- 0	0	4.33	....
1915	91-15	85	4- 7	6	4-14	6	8- 2	9	9-14	10	12- 9	12	19- 8	17	31-15	25	4.00	....
Average	143.2	161	28.0	44	11.0	17	16.9	21	18.3	21	14.0	15	13.5	13	41.3	31	1.94	....
Standard grade—																		
1910	83-15	112	20- 0	33	9-13	14	15-11	21	20- 2	24	13- 2	15	4- 1	4	1- 2	1	....	....
1911	23-10	20	0- 0	0	0-10	1	2-11	3	1-15	2	2- 3	2	2- 4	2	13-15	10	....	....
1912	106-14	146	40-15	69	17- 5	23	22-12	27	9- 4	10	9- 5	10	5- 3	5	2- 2	2	3.20	....
1913	56-11	67	8- 7	18	5-11	7	5- 4	6	7- 2	8	9- 0	9	6- 5	6	14-14	13	1.00	....
1914	59-11	88	38- 3	61	10-10	14	4-10	5	6-14	8	0- 0	0	0- 0	0	0- 0	0	5.33	....
1915	46- 2	45	3-15	6	2-12	3	4- 9	5	8- 2	8	7- 7	7	5-11	5	13-10	11	4.33	....
Average	62.8	80	18.6	31	7.8	10	9.3	11	8.9	10	6.8	7	3.9	4	7.6	6	3.46	....
Cull fruits—																		
1912	5- 6	11	....	....	....	....	....	....	....	....	....	....	....	....	....	....		....
1913	7- 4	31	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	20-14	46	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.33	....
1915	10- 8	17	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.67	....
Average	11.0	26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.00	....
Total crop—																		
1910	216- 1	279	49- 6	79	22- 2	31	35- 5	46	53-11	63	30- 2	34	15- 5	16	10- 2	10	....	....
1911	183- 2	137	1-11	3	1- 6	2	5- 4	6	4-15	5	6- 7	6	7-14	7	155- 9	108	....	....
1912	323-11	457	127- 0	204	41- 6	70	67- 4	83	33- 8	38	28-13	31	14-15	15	5- 7	5	3.13	2
1913	239- 9	273	15- 8	29	13- 9	17	15- 5	18	33-12	37	37- 7	38	40- 2	38	76-10	65	.67	0
1914	169- 6	253	77-15	121	26-14	35	20- 7	25	19- 7	22	2-12	3	1- 1	1	0- 0	0	5.00	0
1915	147-15	147	8- 6	12	7-10	9	12-11	14	18- 0	18	20- 0	19	25- 3	22	45- 9	36	3.67	2
Average	**213.3**	**258**	**46.6**	**75**	**18.8**	**27**	**26.0**	**32**	**27.2**	**31**	**20.8**	**22**	**17.4**	**17**	**48.9**	**37**	**3.12**	**1.00**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
4. Tree No. 23-61-17, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	129- 2	144	9- 3	15	9-10	13	22- 2	27	15-11	18	23-12	25	23- 4	23	25- 8	23	......	......
1911	252- 5	245	13- 7	19	16- 4	20	23-11	27	26-13	28	34-11	34	46-15	43	90- 8	74	......	......
1912	162- 7	162	4-11	7	6-14	9	16- 1	19	19-10	22	23- 3	24	26- 3	25	65-13	56	0.67	......
1913	134-10	161	20- 1	31	23- 4	30	21-15	27	34- 7	38	22- 4	23	8- 3	8	4- 8	4	0	......
1914	96- 1	122	34- 4	52	12- 5	16	14- 8	17	20-14	23	7- 0	7	6- 0	6	1- 2	1	7.33	......
1915	83- 6	86	9-11	13	10- 4	12	11- 2	12	18-11	19	17- 3	16	11-10	10	4-13	4	4.00	......
Average	143.0	153	15.2	23	13.1	17	18.2	22	22.7	25	21.0	22	20.4	19	32.0	27	3.00	......
Standard grade—																		
1910	60- 6	67	5-14	10	7- 5	11	11- 8	15	7- 0	9	13-15	7	6- 8	7	8- 4	8	......	......
1911	56- 8	61	10- 3	16	10- 4	12	1-12	2	5- 7	6	4-13	5	4- 6	4	19-11	16	......	......
1912	84- 8	87	6- 9	10	2-15	4	5-10	7	10-12	12	11- 9	12	16-11	16	30- 6	26	2.00	......
1913	67- 0	86	16-13	30	9- 2	12	9- 1	11	9-10	11	11-12	12	6- 2	6	4- 8	4	1.33	......
1914	58- 8	83	29- 1	47	11-14	15	6-10	9	9-15	11	1- 0	1	0- 0	0	0- 0	0	2.33	......
1915	31- 6	33	5-12	8	1-11	2	4-11	5	7- 0	7	5- 3	5	4- 9	4	2- 8	2	6.00	......
Average	59.7	70	12.4	20	7.2	9	6.5	8	8.3	9	8.0	7	6.3	6	10.9	9	2.92	......
Cull fruits—																		
1912	5- 8	7	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1913	12-11	51	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1914	23- 3	49	......	......	......	......	......	......	......	......	......	......	......	......	......	......	3.00	......
1915	3-15	6	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.00	......
Average	11.3	28	......	......	......	......	......	......	......	......	......	......	......	......	......	......	2.33	......

Total crop—																		
1910	189- 8	211	15- 1	25	16-15	24	33-10	42	22-11	27	37-11	32	29-12	30	33-12	31	....	....
1911	308-13	306	23-10	35	26- 8	32	25- 7	29	32- 4	34	39- 8	39	51- 5	47	110- 3	90	....	....
1912	252- 7	256	11- 4	17	9-13	13	21-11	26	30- 6	34	34-12	36	42-14	41	96- 3	82	1.71	0
1913	214- 5	298	36-14	61	32- 6	42	31- 0	38	44- 1	49	34- 0	35	14- 5	14	9- 0	8	.67	1
1914	177-12	254	63- 5	99	24- 3	31	21- 2	26	30-13	34	8- 0	8	6- 0	6	1- 2	1	4.22	2
1915	118-11	125	15- 7	21	11-15	14	15-13	17	25-11	26	22- 6	21	16- 3	14	7- 5	6	4.67	2
Average	**210.3**	**242**	**27.6**	**43**	**20.3**	**26**	**24.7**	**30**	**31.0**	**34**	**29.4**	**29**	**26.7**	**25**	**42.9**	**36**	**2.82**	**1.25**
5. Tree No. 23-60-16, Marsh strain:																		
Ivory-White grade—																		
1910	144-14	199	61-11	96	16-12	23	31- 2	40	20- 3	24	7-13	9	5- 0	5	2- 5	2	....	....
1911	82-12	55	0- 0	0	0- 0	0	0-14	1	3- 0	3	3- 6	3	8-11	7	66-13	41	....	....
1912	183-13	252	64- 8	104	28- 9	40	30-12	40	35- 9	42	13- 8	15	3-12	4	7- 3	7	1.33	....
1913	126- 3	131	6-13	10	6- 5	8	17- 0	20	25- 1	28	22- 0	22	19- 1	18	29-15	25	1.33	....
1914	87- 8	121	46-13	72	13-14	18	16-10	20	5- 8	6	4-11	5	0- 0	0	0- 0	0	4.33	....
1915	70- 1	69	7-14	10	2- 6	3	10- 0	11	14- 2	14	13-14	13	8- 0	7	13-13	11	6.67	....
Average	115.9	138	31.3	49	11.3	15	17.7	22	17.2	20	10.9	11	7.4	7	20.0	14	3.42	....
Standard grade—																		
1910	93-12	126	47-10	66	9- 0	13	17- 7	23	14- 4	18	5- 7	6	0- 0	0	0- 0	0	....	....
1911	26-13	23	1- 1	2	0-15	1	4- 0	4	4- 1	4	2- 3	2	1- 3	1	13- 6	9	....	....
1912	140-15	187	43- 6	70	21- 1	28	31-14	40	21- 8	25	11-15	13	3-14	4	7- 5	7	2.33	....
1913	87- 6	96	12- 6	20	8-11	11	7-14	9	16- 3	18	10-14	11	6- 4	6	25- 2	21	1.00	....
1914	75- 4	110	44-12	73	10-12	14	7- 6	9	10- 8	12	1-14	2	0- 0	0	0- 0	0	5.00	....
1915	45- 4	45	6-14	10	0- 0	0	8-10	9	9- 4	9	7-14	7	3- 7	3	9- 3	7	2.67	....
Average	78.2	98	26.0	40	8.4	12	12.9	16	12.7	14	6.7	7	2.5	2	9.2	7	2.75	....
Cull fruits—																		
1912	13- 3	24	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	8- 2	30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	25- 4	55	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.67	....
1915	9-15	14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.67	....
Average	14.1	31	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.17	....
Total crop—																		
1910	238-10	325	109- 5	162	25-12	36	48- 9	63	34- 7	42	13- 4	15	5- 0	5	2- 5	2	....	....
1911	109- 9	78	1- 1	2	0-15	1	4-14	5	7- 1	7	5- 9	5	9-14	8	80- 3	50	....	....
1912	337-15	463	107-14	174	49-10	68	62-10	80	57- 1	67	25- 7	28	7-10	8	14- 8	14	2.00	1
1913	221-11	257	19- 3	30	15- 0	19	24-14	29	41- 4	46	32-14	33	25- 5	24	55- 1	46	1.17	0
1914	188- 0	286	91- 9	145	24-10	32	24- 0	29	16- 0	18	6- 9	7	0- 0	0	0- 0	0	5.00	2
1915	125- 4	128	14-12	20	2- 6	3	18-10	20	23- 6	23	21-12	20	11- 7	10	23- 0	18	4.67	1
Average	**203.5**	**256**	**57.3**	**89**	**19.7**	**27**	**30.6**	**38**	**29.9**	**34**	**17.6**	**18**	**9.9**	**9**	**29.2**	**22**	**3.21**	**1.0**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
6. Tree No. 23-60-12, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	161–14	169	6– 1	9	5–11	8	23– 2	28	21– 1	24	17– 7	19	29–14	30	58–10	51	....	....
1911	219–14	208	6– 7	9	3– 5	4	18– 6	21	32– 9	34	21– 4	21	48–13	45	89– 2	74	....	....
1912	176–14	189	16– 3	24	5–14	8	17– 1	21	25– 7	31	24– 5	26	28–15	29	59– 1	50	1.00	....
1913	131– 8	150	14–13	23	16– 7	21	14–14	18	35– 5	39	30– 5	31	9– 4	9	10– 8	9	1.00	....
1914	24–14	34	16– 7	24	4–12	6	0–13	1	2–14	3	0– 0	0	0– 0	0	0– 0	0	6.67	....
1915	71– 0	83	20– 8	31	9–12	12	11–11	13	6– 0	6	15–14	15	3– 7	3	3–12	3	6.00	....
Average	131.0	139	13.4	20	7.6	10	14.3	17	20.5	23	18.2	19	20.0	19	36.8	31	3.67	....
Standard grade—																		
1910	46– 9	56	6–13	10	3– 1	4	4–12	7	5–15	8	3– 9	4	6–13	8	15–10	15	....	....
1911	64–10	67	7– 3	10	3– 5	4	9–10	11	7–11	8	15– 6	15	7– 6	7	14– 1	12	....	....
1912	81– 7	86	6–11	11	2– 3	3	8– 0	10	9– 0	10	12– 7	13	14– 4	14	28–14	25	.50	....
1913	65– 9	82	18–11	31	12– 5	16	7– 0	8	8– 6	9	7– 3	7	5– 3	5	6–13	6	1.00	....
1914	42– 8	59	24– 8	39	8– 2	10	0–14	1	5–14	6	2– 0	2	1– 2	1	0– 0	0	5.00	....
1915	55– 8	63	12–15	20	10– 4	12	6– 7	7	9–14	10	8–12	8	3–10	3	3–10	3	6.00	....
Average	59.4	69	12.7	20	6.5	8	6.1	7	7.8	8	8.2	8	6.4	7	11.5	10	3.12	....
Cull fruits—																		
1912	6– 5	8	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1913	7–12	47	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	....
1914	19– 8	37	....	......	....	......	....	......	....	......	....	......	....	......	....	......	5.00	....
1915	19– 3	34	....	......	....	......	....	......	....	......	....	......	....	......	....	......	7.00	....
Average	13.2	32	....	......	....	......	....	......	....	......	....	......	....	......	....	......	6.00	....

Total crop—																		
1910	208- 7	225	12-14	19	8-12	12	27-14	35	27- 0	32	21- 0	23	36-11	38	74- 4	66	....	....
1911	284- 8	275	13-10	19	6-10	8	28- 0	32	40- 4	42	36-10	36	56- 3	52	103- 3	86	....	....
1912	264-10	283	22-14	35	8- 1	11	25- 1	31	34- 7	41	36-12	39	43- 3	43	87-15	75	.67	0
1913	204-13	279	33- 8	54	28-12	37	21-14	26	43-11	48	37- 8	38	14- 7	14	17- 5	15	1.00	0
1914	86-14	130	40-15	63	12-14	16	1-11	2	8-12	9	2- 0	2	1- 2	1	0- 0	0	5.56	2
1915	145-11	180	33- 7	51	20- 0	24	18- 2	20	15-14	16	24-10	23	7- 1	6	7- 6	6	6.33	4
Average	**199.2**	**229**	**26.2**	**40**	**14.2**	**18**	**20.4**	**24**	**28.3**	**31**	**26.4**	**27**	**26.4**	**26**	**48.3**	**41**	**3.39**	**1.50**
7. Tree No. 23-59-15, Marsh strain:																		
Ivory-White grade—																		
1910	140- 0	183	51- 0	77	18-13	25	31- 1	38	18-10	22	8- 1	9	4- 1	4	8- 6	8	....	....
1911	116- 8	98	7- 0	10	2-11	3	8- 4	9	6-14	7	10-10	10	8-15	8	72- 2	51	....	....
1912	164-13	196	28- 8	45	13-11	18	32- 9	40	21- 2	24	35- 1	37	15- 4	15	18-10	17	2.67	....
1913	129- 0	137	13- 4	19	13- 8	17	12-14	15	27- 9	29	23-13	24	17- 8	16	20- 8	17	.67	....
1914	133- 2	183	67-12	105	28-14	37	18-11	22	9- 0	10	6-11	7	2- 2	2	0- 0	0	4.33	....
1915	58- 1	56	4- 6	6	3- 7	4	8- 6	9	7- 0	7	9-12	9	9- 0	8	16- 2	13	3.00	....
Average	123.6	142	28.6	44	13.5	17	18.6	22	15.0	17	15.6	16	9.5	9	22.6	18	2.67	....
Standard grade—																		
1910	43-10	65	17-11	30	8- 4	12	8- 2	11	5- 1	7	2- 9	3	0-15	1	1- 0	1	....	....
1911	50- 0	44	1- 7	2	3- 7	4	6-14	7	2-14	3	4- 5	4	9- 3	8	21-14	16	....	....
1912	135-14	160	24- 4	38	12- 3	16	25- 6	31	14- 6	16	29- 7	31	17- 6	17	12-14	11	.83	....
1913	47- 8	54	9-12	14	7- 4	9	6- 1	7	10- 4	11	3-15	4	5- 6	5	4-14	4	.67	....
1914	31-13	45	13-15	23	7-11	10	5-14	7	3- 6	4	0-15	1	0- 0	0	0- 0	0	4.67	....
1915	44- 0	44	6- 2	9	1-11	2	4-10	5	3- 2	3	13-14	13	7- 1	6	7- 8	6	6.33	....
Average	58.8	69	12.2	19	6.7	9	9.5	12	6.5	7	9.2	9	6.6	6	8.0	6	3.13	....
Cull fruits—																		
1912	1- 7	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	11- 3	44	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	8-11	25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.67	....
1915	4-14	7	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.67	....
Average	6.5	20	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.67	....
Total crop—																		
1910	183-10	248	68-11	107	27- 1	37	39- 3	49	23-11	29	10-10	12	5- 0	5	9- 6	9	....	....
1911	166- 8	142	8- 7	12	6- 2	7	15- 2	16	9-12	10	14-15	14	18- 2	16	94- 0	67	....	....
1912	302- 2	359	52-12	83	25-14	34	57-15	71	35- 8	40	64- 8	68	32-10	32	31- 8	28	1.44	0
1913	187-11	235	23- 0	33	20-12	26	18-15	22	37-13	40	27-12	28	22-14	21	25- 6	21	.67	0
1914	173-10	253	81-11	128	36- 9	47	24- 9	29	12- 6	14	7-10	8	2- 2	2	0- 0	0	3.89	3
1915	106-15	107	10- 8	15	5- 2	6	13- 0	14	10- 2	10	23-10	22	10- 1	14	23-10	19	4.00	0
Average	**186.8**	**224**	**40.8**	**63**	**20.3**	**26**	**28.1**	**34**	**21.5**	**24**	**24.8**	**25**	**16.1**	**15**	**30.6**	**24**	**2.50**	**0.75**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
8. Tree No. 23-61-21, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	138- 3	184	60- 7	91	24- 1	31	20-10	26	20- 8	23	8- 5	9	3- 1	3	1- 3	1	....	....
1911	162- 7	145	10- 3	13	6-15	8	10- 1	11	12- 1	12	19-13	19	15-11	14	87-11	68	....	....
1912	146- 3	175	26- 2	41	16- 6	22	23- 2	28	27- 4	31	24- 9	26	11- 2	11	17-10	16	1.00	....
1913	104-12	126	25- 7	38	20- 5	26	15- 4	18	19- 3	21	8-15	9	7- 8	7	8- 2	7	1.00	....
1914	55- 2	79	36- 0	56	6- 2	8	7-12	9	5- 4	6	0- 0	0	0- 0	0	0- 0	0	3.33	....
1915	98- 7	105	16- 7	22	12-15	15	17- 6	19	22-11	23	12- 8	12	10- 5	9	6- 3	5	7.67	....
Average	117.5	136	29.1	44	14.5	18	15.7	19	17.8	19	12.4	13	7.9	7	20.1	16	3.25	....
Standard grade—																		
1910	44- 5	65	20- 8	33	8- 8	12	6- 9	9	6-14	9	1-14	2	0- 0	0	0- 0	0	....	....
1911	54- 9	60	10-15	19	3-12	4	7- 8	8	6-13	7	5- 8	5	8-14	8	11- 3	9	....	....
1912	104- 0	122	23- 3	36	10- 8	14	17- 9	21	15- 9	16	12- 8	13	9- 7	9	15- 4	13	.50	....
1913	52-15	69	18-11	30	7-11	10	10- 5	12	8- 3	9	3-14	4	3- 0	3	1- 3	1	2.00	....
1914	57- 3	86	40-14	66	9- 5	12	4- 6	5	2-10	3	0- 0	0	0- 0	0	0- 0	0	7.00	....
1915	59- 3	65	13- 5	18	11- 5	13	9- 4	10	10-12	11	4- 1	4	6-14	6	3-10	3	4.67	....
Average	62.0	78	21.3	33	8.5	11	9.3	10	8.5	10	4.6	4	4.7	5	5.2	5	3.54	....
Cull fruits—																		
1912	0- 9	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	6-15	46	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	18- 2	36	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.67	....
1915	2- 3	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.00	....
Average	7.0	22	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.84	....

Total crop—																		
1910	182- 8	249	80-15	124	32- 9	43	27- 3	35	27- 6	32	10- 3	11	3- 1	3	1- 3	1	....	....
1911	217- 0	205	21- 2	32	10-11	12	17- 9	19	18-14	19	25- 5	24	24- 9	22	98-14	77	....	....
1912	250-12	298	49- 5	77	26-14	36	40-11	49	42-13	47	37- 1	39	20- 9	20	32-14	29	.67	1
1913	164-10	241	44- 2	68	28- 0	36	25- 9	30	27- 6	30	12-13	13	10- 8	10	9- 5	8	1.50	1
1914	130- 7	201	76-14	122	15- 7	20	12- 2	14	7-14	9	0- 0	0	0- 0	0	0- 0	0	4.67	1
1915	159-13	174	29-12	40	24- 4	28	26-10	29	33- 7	34	16- 9	16	17- 3	15	9-13	8	5.63	3
Average	**184.2**	**228**	**50.4**	**77**	**23.0**	**29**	**25.0**	**29**	**26.3**	**29**	**17.0**	**17**	**12.6**	**12**	**25.3**	**21**	**3.12**	**1.50**
9. Tree No. 23-61-20, Marsh strain:																		
Ivory-White grade—																		
1910	80- 4	134	43- 2	83	8-12	20	14-13	16	9- 9	11	1-13	2	2- 3	2	0- 0	0	....	....
1911	100- 4	72	2- 6	3	2- 6	3	0-13	1	2-12	3	1- 1	1	3-10	3	87- 4	58	....	....
1912	159- 3	204	27- 9	44	37- 9	51	31-11	40	27- 4	32	24-14	27	3-15	4	6- 5	6	4.33	....
1913	155-11	159	7- 2	11	17-11	22	16-10	19	32-13	35	24-14	24	22- 1	20	34- 8	28	1.67	....
1914	69- 7	97	35-10	56	16-14	22	8- 8	10	4- 8	5	3-15	4	0- 0	0	0- 0	0	5.33	....
1915	102- 7	113	27-15	39	8- 8	10	20- 8	22	9-12	10	15-11	15	10- 3	9	9-14	8	5.00	....
Average	111.2	130	24.0	39	15.3	21	15.5	18	14.4	16	12.0	12	7.0	6	23.0	16	4.08	....
Standard grade—																		
1910	69-11	126	44-15	84	4- 2	16	11-10	15	7- 3	9	0-14	1	0-15	1	0- 0	0	....	....
1911	19- 5	18	2-15	4	1-13	2	0- 0	0	3- 2	3	1- 2	1	4- 9	4	5-12	4	....	....
1912	127- 5	159	30- 2	46	20- 4	27	28- 1	34	18- 8	21	16-14	18	8- 0	8	5- 8	5	2.67	....
1913	56-12	64	7- 2	11	10- 5	13	9- 9	11	11- 4	12	8-15	9	2- 4	2	7- 5	6	.33	....
1914	54-14	81	37-10	60	6-15	9	6-14	8	3- 7	4	0- 0	0	0- 0	0	0- 0	0	3.67	....
1915	69-10	80	21- 6	31	7-11	9	12- 4	13	12- 0	12	11-12	11	3- 6	3	1- 3	1	3.67	....
Average	66.3	88	24.0	40	8.5	13	11.4	14	9.3	10	6.6	7	3.2	3	3.3	3	2.58	....
Cull fruits—																		
1912	4- 0	8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	6- 9	26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	18- 9	34	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.33	....
1915	2- 8	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.33	....
Average	7.9	18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.33	....
Total crop—																		
1910	149-15	260	88- 1	167	12-14	36	26- 7	31	16-12	20	2-11	3	3- 2	3	0- 0	0	....	....
1911	119- 9	90	5- 5	7	4- 3	5	0-13	1	5-14	6	2- 3	2	8- 3	7	93- 0	62	....	....
1912	290- 8	371	57-11	90	57-13	78	59-12	74	45-12	53	41-12	45	11-15	12	11-13	11	3.22	0
1913	219- 0	249	14- 4	22	28- 0	35	26- 3	30	44- 1	47	33-13	33	24- 5	22	41-13	34	1.00	2
1914	142-14	212	73- 4	116	23-13	31	15- 6	18	7-15	9	3-15	4	0- 0	0	0- 0	0	4.11	4
1915	174- 9	198	49- 5	70	16- 3	19	32-12	35	21-12	22	27- 7	26	13- 9	12	11- 1	9	4.00	0
Average	**182.7**	**230**	**48.0**	**79**	**23.8**	**34**	**26.9**	**32**	**23.7**	**26**	**18.6**	**19**	**10.2**	**9**	**26.3**	**19**	**3.08**	**1.50**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
10. Tree No. 23-61-11, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	128- 6	180	59-13	93	24- 4	33	24- 8	31	13- 7	16	4- 8	5	0-14	1	1- 0	1	......	......
1911	194- 6	195	11- 1	16	5- 5	7	12-15	15	20-15	23	34- 4	37	33- 2	32	76-12	65	......	......
1912	171-15	222	44- 3	71	29- 5	39	33- 5	42	26-10	31	24- 1	25	7-13	8	6-10	6	1.67	......
1913	91- 9	103	6-12	11	10- 8	14	9-15	12	23- 3	26	19-12	20	16-15	16	4- 8	4	0	......
1914	80- 3	115	46- 5	73	20-12	27	7-12	9	5- 6	6	0- 0	0	0- 0	0	0- 0	0	5.67	......
1915	56-14	59	7-10	10	6-10	8	10- 1	11	11- 3	11	10-12	10	8- 0	7	2-10	2	4.00	......
Average	120.6	146	29.3	46	16.1	21	16.4	20	16.8	19	15.6	16	11.1	10	15.3	13	2.84	......
Standard grade—																		
1910	71-15	99	24- 7	40	15- 3	20	16- 8	21	13-15	16	1-14	2	0- 0	0	0- 0	0	......	......
1911	74- 3	77	3-11	6	4-10	6	9- 2	11	11-13	13	8-13	9	10- 9	10	25- 9	22	......	......
1912	86- 6	115	26-11	43	13- 6	18	24- 3	30	11- 4	13	4- 9	5	2- 0	2	4- 5	4	4.33	......
1913	38- 2	51	12- 2	22	5- 8	7	4-15	6	7- 6	8	3-15	4	3- 3	3	1- 1	1	2.00	......
1914	43- 1	68	31-12	54	7- 2	9	3- 4	4	0-15	1	0- 0	0	0- 0	0	0- 0	0	4.00	......
1915	20-15	23	4- 6	6	3- 5	4	3-10	4	5- 0	5	2- 1	2	1- 3	1	1- 6	1	5.33	......
Average	55.8	72	17.2	28	8.2	11	10.3	13	8.4	9	3.5	4	2.8	3	5.3	5	4.42	......
Cull fruits—																		
1912	5- 3	10	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1913	8-15	42	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1914	13- 9	31	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.67	......
1915	9-14	15	......	......	......	......	......	......	......	......	......	......	......	......	......	......	3.67	......
Average	9.4	25	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.17	......

Total crop—																		
1910	200- 5	279	84- 4	133	39- 7	53	41- 0	52	27- 6	32	6- 6	7	0-14	1	1- 0	1	....	....
1911	268- 9	272	14-12	22	9-15	13	22- 1	26	32-12	36	43- 1	46	43-11	42	102- 5	87	....	....
1912	263- 8	347	70-14	114	42-11	57	57- 8	72	37-14	44	28-10	30	9-13	10	10-15	10	3.33	0
1913	138-10	196	18-14	33	16- 0	21	14-14	18	30- 9	34	23-11	24	20- 2	19	5- 9	5	2.00	0
1914	136-13	214	78- 1	127	27-14	36	11- 0	13	6- 5	7	0- 0	0	0- 0	0	0- 0	0	4.78	1
1915	87-11	97	12- 0	16	9-15	12	13-11	15	16- 3	16	12-13	12	9- 3	8	4- 0	3	4.33	1
Average	**182.6**	**234**	**46.5**	**74**	**24.3**	**32**	**26.7**	**33**	**25.2**	**28**	**19.1**	**20**	**13.9**	**13**	**20.6**	**18**	**3.61**	**0.50**
11. Tree No. 23-63-21, Marsh strain:																		
Ivory-White grade—																		
1910	126- 2	172	47- 4	73	22-13	31	24- 6	31	18- 7	22	5- 2	6	6- 1	7	2- 1	2	....	....
1911	180- 5	137	0-15	2	0-10	1	4- 7	5	3-13	4	7- 6	7	14- 7	13	148-11	105	....	....
1912	190- 4	237	42- 4	67	29- 3	39	34- 3	42	31-12	36	23- 6	25	15- 3	15	14- 5	13	1.00	....
1913	128-13	144	12-15	20	21- 9	27	23- 2	27	18- 7	20	21- 0	21	19- 4	18	12- 8	11	0	....
1914	63- 4	84	28- 2	42	19- 4	24	7- 8	9	5- 8	6	2-14	3	0- 0	0	0- 0	0	5.00	....
1915	66-10	71	14- 2	18	10- 3	12	7- 7	8	16- 0	16	9- 9	9	5-12	5	3- 9	3	5.67	....
Average	125.9	141	24.3	37	17.3	22	16.8	20	15.7	17	11.6	12	10.1	10	30.2	22	2.92	....
Standard grade—																		
1910	69- 4	100	25- 3	42	12-15	19	16-6	22	7-14	10	4- 0	4	2-14	3	0- 0	0	....	....
1911	24- 8	23	1- 1	2	0- 0	0	2-12	3	0- 0	0	1-14	2	7- 9	7	11- 4	9	....	....
1912	82- 5	112	36- 9	58	12- 2	16	8- 1	12	7- 7	8	6-11	7	6- 1	6	5- 6	5	1.67	....
1913	45-13	67	12- 2	30	13- 8	17	5- 6	6	6- 9	7	2- 2	2	1- 2	1	5- 0	4	6.67	....
1914	54-10	81	37- 2	60	7-12	10	2- 4	3	3- 8	4	2-14	3	1- 2	1	0- 0	0	5.67	....
1915	35- 3	36	5- 0	7	2-10	3	6-10	7	9- 2	9	2- 2	2	5-14	5	3-13	3	5.33	....
Average	51.9	70	19.5	33	8.1	11	7.0	9	5.7	7	3.2	3	4.1	4	4.2	4	4.84	....
Cull fruits—																		
1912	4-11	8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	5-10	29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	11-10	24	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.00	....
1915	0-13	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.00	....
Average	5.7	16	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.00	....
Total crop—																		
1910	195- 6	272	72- 7	115	35-12	50	40-12	53	26- 5	32	9- 2	10	8-15	10	2- 1	2	....	....
1911	204-13	160	2- 0	4	0-10	1	7- 3	8	3-13	4	9- 4	9	22- 0	20	159-15	114	....	....
1912	277- 4	357	78-13	125	41- 5	55	42- 4	54	39- 3	44	30- 1	32	21- 4	21	19-11	18	1.44	0
1913	180- 4	240	25- 1	50	35- 1	44	28- 8	33	25- 0	27	23- 2	23	20- 6	19	17- 8	15	3.33	1
1914	129- 8	189	65- 4	102	27- 0	34	9-12	12	9- 0	10	5-12	6	1- 2	1	0- 0	0	5.22	1
1915	102-10	108	19- 2	25	12-13	15	14- 1	15	25- 2	25	11-11	11	11-10	10	7- 6	6	5.43	2
Average	**181.6**	**221**	**43.8**	**70**	**25.4**	**33**	**23.8**	**29**	**21.4**	**24**	**14.8**	**15**	**14.2**	**14**	**34.4**	**26**	**3.85**	**1.00**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
12. Tree No. 23-60-11, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	122-15	144	21- 7	34	9- 6	13	18-10	24	15- 8	18	15-12	17	14- 1	14	28- 3	24	......	......
1911	244- 9	237	12- 2	18	9- 9	12	29-12	34	19- 8	21	21- 2	21	36- 9	35	115-15	96	......	......
1912	162- 1	151	3-14	6	5- 6	7	10-15	13	15-10	17	11-13	12	22-15	22	91- 8	74	0	......
1913	129- 7	148	17-11	27	18- 8	24	21- 4	25	28- 9	31	14- 7	15	13-10	13	15- 6	13	1.00	......
1914	33- 0	42	14- 1	21	7- 5	9	3-10	4	5-14	6	2- 2	2	0- 0	0	0- 0	0	4.00	......
1915	48- 4	51	9- 7	13	3- 6	4	6- 5	7	8-12	9	9- 8	9	3- 8	3	7- 6	6	5.00	......
Average	123.4	129	13.1	20	8.9	11	15.1	18	15.6	17	12.5	13	15.1	15	43.1	36	2.50	......
Standard grade—																		
1910	72- 7	99	10-14	21	6-14	11	11-18	17	12- 7	16	15- 7	18	5- 9	7	9- 2	9	......	......
1911	37- 6	41	6- 0	9	2-14	4	4- 2	5	1-12	2	4-10	5	1-15	2	16- 1	14	......	......
1912	29- 0	29	1-10	3	2- 8	3	2- 8	3	3-12	4	3-12	4	2- 0	2	12-14	10	.83	......
1913	67- 7	86	16- 2	32	8- 0	10	7-14	9	10- 2	11	10- 0	10	9- 9	9	5-12	5	3.00	......
1914	44- 0	53	11-10	18	10- 1	12	10- 0	11	7-11	8	2- 4	2	0- 0	0	2- 6	2	3.33	......
1915	47-13	51	8-13	12	6- 0	7	8- 6	9	9- 3	9	8- 3	8	1- 3	1	6- 1	5	4.00	......
Average	49.7	60	9.2	16	6.1	8	7.5	9	7.5	8	7.3	8	3.4	3	8.7	7	2.79	......
Cull fruits—																		
1912	0- 0	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1913	7- 4	36	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1914	8- 1	7	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.00	......
1915	20- 6	34	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.67	......
Average	8.9	36	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.33	......

Total crop—																		
1910	195- 6	243	32- 5	55	16- 4	24	30-12	41	27-15	34	31- 3	35	19-10	21	37- 5	33	....	....
1911	281-15	278	18- 2	27	12- 7	16	33-14	39	21- 4	23	25-12	26	38- 8	37	132- 0	110	....	....
1912	191- 1	180	5- 8	9	7-14	10	13- 7	16	19- 6	21	15- 9	16	24-15	24	104- 6	84	.56	0
1913	204- 2	270	33-13	59	26- 8	34	29- 2	34	38-11	42	24- 7	25	23- 3	22	21- 2	18	2.00	1
1914	85- 1	112	25-11	39	17- 6	21	13-10	15	13- 9	14	4- 6	4	0- 0	0	2- 6	2	3.78	4
1915	116- 7	136	18- 4	25	9- 6	11	14-11	16	17-15	18	17-11	17	4-11	4	13- 7	11	4.56	2
Average	**179.0**	**203**	**22.3**	**36**	**15.0**	**19**	**22.6**	**27**	**23.1**	**25**	**19.8**	**21**	**18.5**	**18**	**51.8**	**43**	**2.73**	**1.75**
13. Tree No. 23-60-9, Marsh strain:																		
Ivory-White grade—																		
1910	164 -1	203	48- 0	73	22- 9	30	19- 7	24	16- 9	19	20- 9	22	11-14	12	25- 1	23	....	....
1911	175-11	182	16- 2	22	15-13	19	27-12	31	36- 2	38	23- 0	23	22- 0	20	34-14	29	....	....
1912	197- 4	241	37- 3	58	26- 1	35	41-12	52	26-13	31	23- 8	25	18-11	19	23- 4	21	.67	....
1913	76- 1	83	4- 7	8	8-13	11	9-11	11	14- 7	16	17- 0	17	14-10	14	7- 1	6	1.67	....
1914	50- 7	70	27-14	43	8- 8	11	5- 0	6	7- 3	8	1-14	2	0- 0	0	0- 0	0	7.00	....
1915	45- 0	46	2-13	4	2-10	3	13- 0	14	10-10	11	6- 6	6	5- 9	5	4- 0	3	3.67	....
Average	118.1	138	22.7	35	14.1	18	19.4	23	18.6	21	15.4	16	12.1	12	15.7	14	3.25	....
Standard grade—																		
1910	47- 0	64	12-14	22	7- 5	10	9- 4	12	9- 3	11	4- 8	5	1-14	2	2- 0	2	....	....
1911	87- 8	97	14-10	21	9-12	12	12- 4	14	17- 3	18	14-14	15	8-10	8	10- 3	9	....	....
1912	70-12	93	22-12	38	6-14	9	12-12	16	12- 4	14	9- 8	10	2- 2	2	4- 8	4	1.67	....
1913	28- 5	38	8- 2	16	5-10	7	2- 7	3	4-11	5	3- 1	3	3- 4	3	1- 2	1	2.67	....
1914	49-10	73	30-10	50	9- 4	12	3- 6	4	6- 6	7	0- 0	0	0- 0	0	0- 0	0	3.00	....
1915	32- 2	35	6- 6	9	2- 6	3	5- 6	6	5- 0	5	5- 8	5	3- 7	3	4- 1	4	5.00	....
Average	52.6	66	15.9	26	6.8	9	7.6	9	9.1	10	6.2	6	3.2	3	3.7	3	3.09	....
Cull fruits—																		
1912	2- 1	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	7- 3	38	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	11-14	30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.67	....
1915	5- 6	7	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.00	....
Average	6.6	20	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.34	....
Total crop—																		
1910	211- 1	267	60-14	95	29-14	40	28-11	36	25-12	30	25- 1	27	13-12	14	27- 1	25	....	....
1911	263- 3	279	30-12	43	25- 9	31	40- 0	45	53- 5	56	37-14	38	30-10	28	45- 1	38	....	....
1912	270- 1	338	59-15	96	32-15	44	54- 8	68	39- 1	45	33- 0	35	20-13	21	27-12	25	1.33	0
1913	111- 9	159	12- 9	24	14- 7	18	12- 2	14	19- 2	21	20- 1	20	17-14	17	8- 3	7	2.17	1
1914	111-15	173	58- 8	93	17-12	23	8- 6	10	13- 9	15	1-14	2	0- 0	0	0- 0	0	4.22	1
1915	82- 8	88	9- 3	13	5- 0	6	18- 6	20	15-10	16	11-14	11	9- 0	8	8- 1	7	3.56	7
Average	**175.1**	**217**	**38.6**	**61**	**20.9**	**27**	**27.0**	**32**	**27.7**	**31**	**21.6**	**22**	**15.3**	**15**	**19.4**	**17**	**2.82**	**2.25**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
14. Tree No. 23-62-16, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	130–10	178	55–13	89	10–14	15	24–10	31	17–14	21	5–13	7	7– 5	8	8– 5	7	....	....
1911	193–13	189	4– 9	7	11– 0	14	19– 2	22	22– 7	24	26–12	27	35–11	33	74– 4	62	....	....
1912	149– 3	166	13– 9	21	10– 9	14	17–15	22	28– 7	33	24– 9	26	18– 6	18	35–12	32	1.00	....
1913	84–11	96	6– 9	10	9–14	13	15–12	19	16–13	19	16– 7	17	12– 6	12	6–14	6	.67	....
1914	51–15	73	28– 0	44	11–12	15	6–12	8	4– 8	5	0–15	1	0– 0	0	0– 0	0	5.00	....
1915	80– 9	84	12–15	18	8– 8	10	9– 0	10	23– 8	23	14– 8	13	5–14	5	6– 4	5	4.00	....
Average	115.1	131	20.2	32	10.4	14	15.5	19	18.9	21	14.8	15	13.3	13	21.9	19	2.67	....
Standard grade—																		
1910	75–11	116	38–14	66	5–14	9	17– 1	23	8–11	12	1–13	2	2– 5	3	1– 1	1	....	....
1911	55– 0	61	7– 2	11	3–10	5	8–12	10	7– 6	8	9–12	10	11– 7	11	6–15	6	....	....
1912	49– 7	56	7– 2	12	5–12	8	6– 6	8	6– 7	7	6– 6	6	3– 1	3	14– 5	12	.83	....
1913	46– 1	59	13– 0	23	9–12	12	6– 0	7	4–12	5	6– 0	6	3– 3	3	3– 6	3	0	....
1914	49– 7	74	32–10	55	4–12	6	2– 8	3	6– 8	7	3– 1	3	0– 0	0	0– 0	0	5.33	....
1915	43– 7	45	6–11	9	4– 3	5	9– 4	10	8– 3	8	7–12	7	4–12	4	2–10	2	5.00	....
Average	53.2	69	17.6	29	5.7	7	8.4	10	7.0	8	5.8	6	4.1	4	4.6	4	2.79	....
Cull fruits—																		
1912	12– 4	18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	7–13	28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	14– 4	32	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.00	....
1915	3– 1	6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.67	....
Average	9.3	21	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.35	....

Total crop—																		
1910	206– 5	294	94–11	155	16–12	24	41–11	54	26– 9	33	7–10	9	9–10	11	9– 6	8	....	....
1911	248–13	250	11–11	18	14–10	19	27–14	32	29–13	32	36– 8	37	47– 2	44	81– 3	68	....	....
1912	210–14	240	20–11	33	16– 5	22	24– 5	30	34–14	40	30–15	32	21– 7	21	50– 1	44	.89	0
1913	138– 9	183	19– 9	33	19–10	25	21–12	26	21– 9	24	22– 7	23	15– 9	15	10– 4	9	.33	1
1914	115–10	179	60–10	99	16– 8	21	9– 4	11	11– 0	12	4– 0	4	0– 0	0	0– 0	0	5.11	2
1915	127– 1	135	19–10	27	12–11	15	18– 4	20	31–11	31	22– 4	20	10–10	9	8–14	7	4.22	2
Average	**174.5**	**214**	**37.8**	**61**	**16.1**	**21**	**23.9**	**29**	**25.9**	**29**	**20.6**	**21**	**17.4**	**17**	**26.6**	**23**	**2.64**	**1.25**
15. Tree No. 23-60-8, Marsh strain:																		
Ivory-White grade—																		
1910	138–10	183	52–15	80	19–11	26	33– 1	41	16– 5	19	11– 6	12	4– 2	4	1– 2	1	....	....
1911	167–15	156	3–14	4	6– 8	8	6– 0	7	19–10	21	19– 4	19	35–10	33	77– 1	64	....	....
1912	193– 4	210	17– 1	25	13–11	18	32–10	39	39–13	44	29– 6	30	28– 4	27	32– 7	27	.67	....
1913	102– 1	111	9– 5	14	9–15	13	7– 0	8	27–10	30	24–13	25	13–14	13	9– 8	8	1.00	....
1914	61– 7	84	31– 2	48	16–13	21	7–14	9	5–10	6	0– 0	0	0– 0	0	0– 0	0	7.67	....
1915	46– 4	47	6– 7	9	2– 9	3	8– 6	9	9– 2	9	6–10	6	10–12	9	2– 6	2	4.67	....
Average	118.3	132	20.1	30	11.5	15	15.8	19	19.7	22	15.2	15	15.4	14	20.4	17	3.50	....
Standard grade—																		
1910	40– 0	55	14– 5	23	6– 5	9	8– 9	11	6–14	8	2–15	3	0– 0	0	1– 0	1	....	....
1911	54– 2	52	1– 9	2	2– 6	3	4– 8	4	8– 7	9	6–15	7	7– 1	7	23– 4	20	....	....
1912	56–11	63	7– 5	11	7– 3	9	9–12	11	7– 7	8	6–12	7	9– 3	9	9– 1	8	2.00	....
1913	64– 8	78	13– 1	22	10– 3	13	10– 1	12	11– 0	12	9– 0	9	7– 5	7	3–14	3	1.00	....
1914	43–15	62	24–10	39	7– 4	9	10– 6	12	1–11	2	0– 0	0	0– 0	0	0– 0	0	5.67	....
1915	28– 3	30	4–14	7	5– 2	6	3–10	4	4– 2	4	6–10	6	1– 3	1	2–10	2	5.00	....
Average	47.9	57	11.0	17	6.4	8	7.8	9	6.6	7	5.4	6	4.2	4	6.6	6	3.42	....
Cull fruits—																		
1912	5–13	9	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	10–13	48	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	20– 6	45	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.00	....
1915	4–11	7	....	....	....	....	....	....	....	....	....	....	....	....	....	....	8.00	....
Average	10.4	27	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.50	....
Total crop—																		
1910	178–10	238	67– 4	103	26– 0	35	41–10	52	23– 3	27	14– 5	15	4– 2	4	2– 2	2	....	....
1911	222– 1	208	5– 7	6	8–14	11	10– 8	11	28– 1	30	26– 3	26	42–11	40	100– 5	84	....	....
1912	255–12	282	24– 6	36	20–14	27	42– 6	50	47– 4	52	36– 2	37	37– 7	36	41– 8	35	1.56	0
1913	177– 6	237	22– 6	36	20– 2	26	17– 1	20	38–10	42	33–13	34	21– 3	20	13– 6	11	1.00	0
1914	125–12	191	55–12	87	24– 1	30	18– 4	21	7– 5	8	0– 0	0	0– 0	0	0– 0	0	6.11	1
1915	79– 2	84	11– 5	16	7–11	9	12– 0	13	13– 4	13	13– 4	12	11–15	10	5– 0	4	5.89	0
Average	**173.1**	**207**	**31.1**	**47**	**17.9**	**23**	**23.6**	**28**	**26.3**	**29**	**20.6**	**21**	**19.6**	**18**	**27.1**	**23**	**3.64**	**0.25**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
16. Tree No. 23-59-7, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	109-13	143	31- 1	51	15- 8	21	19-11	25	12- 1	14	11-15	13	8- 4	9	10-11	10	....	....
1911	146- 0	126	2-14	4	1-10	2	2-12	3	9- 6	10	16- 6	16	24-10	22	88- 6	69	....	....
1912	176- 5	207	27-10	42	14- 4	19	32- 0	39	30-14	35	32- 9	35	18- 0	18	21- 0	19	.67	....
1913	111-11	125	9-13	16	15- 0	19	15-13	19	29-10	32	15- 0	15	14-10	14	11-13	10	2.00	....
1914	67- 8	91	29-10	46	16- 7	21	13- 1	15	7- 8	8	0-14	1	0- 0	0	0- 0	0	6.33	....
1915	82-12	87	10-13	15	3- 6	4	12- 8	14	20- 7	21	18- 8	18	12- 2	11	5- 0	4	5.00	....
Average	115.7	130	18.6	29	11.0	14	16.0	19	18.3	20	15.9	16	12.9	12	22.8	19	3.50	....
Standard grade—																		
1910	69- 4	97	14-13	28	11- 7	17	13- 7	18	13-13	17	5-14	7	5-13	6	4- 1	4	....	....
1911	75- 6	68	2- 0	4	5- 3	6	6- 6	7	4-13	5	9- 2	9	8-12	8	39- 2	29	....	....
1912	72- 2	90	18- 2	29	9-10	13	13- 5	16	9-13	11	9- 6	10	4- 0	4	7-14	7	1.50	....
1913	28- 8	38	8- 9	16	6- 6	8	3- 7	4	4-10	5	3- 0	3	0- 0	0	2- 8	2	3.67	....
1914	40- 5	55	19- 0	29	10- 0	13	8- 8	10	1-11	2	0- 0	0	1- 2	1	0- 0	0	8.00	....
1915	23- 9	25	2-15	4	3- 4	4	4- 7	5	5- 3	5	3- 3	3	3- 4	3	1- 5	1	7.00	....
Average	51.5	62	11.0	18	7.7	10	8.3	10	6.7	8	5.1	6	3.9	4	9.2	7	5.04	....
Cull fruits—																		
1912	6- 9	14	....	....	....	....	....	....	....	....	....	....	....	....	....	....		....
1913	9- 1	35	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	9-12	20	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.33	....
1915	2-10	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.00	....
Average	7.0	18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.67	....

1910	179- 1	240	46- 8	79	26-15	38	33- 2	43	25-14	31	17-13	20	14- 1	15	14-12	14	....	....
1911	221- 6	194	4 14	8	6-13	8	9- 2	10	14- 3	15	25- 8	25	33- 6	30	127- 8	98	....	....
1912	255- 0	311	45-12	71	23-14	32	45- 5	55	40-11	46	41-15	45	22- 0	22	28-14	26	1.22	6
1913	149- 4	198	18- 6	32	21- 6	27	19- 4	23	34- 4	37	18- 0	18	14-10	14	14- 5	12	2.83	0
1914	117- 9	166	48-10	75	26- 7	34	21- 9	25	9- 3	10	0-14	1	1- 2	1	0- 0	0	6.22	4
1915	108-15	116	13-12	19	6-10	8	16-15	19	25-10	26	21-11	21	15- 6	14	6- 5	5	5.67	1
Average	**171.9**	**204**	**29.6**	**47**	**18.7**	**24**	**24.2**	**29**	**25.0**	**28**	**21.0**	**22**	**16.8**	**16**	**32.0**	**26**	**3.99**	**2.75**
17. Tree No. 23-63-15, Marsh strain:																		
Ivory-White grade—																		
1910	141- 0	179	35-14	57	21-10	29	24- 1	30	23- 6	27	15- 4	16	7-12	8	13- 1	12	....	....
1911	148- 2	146	11-12	16	9- 2	11	12- 4	14	20-14	22	30- 8	30	20-12	19	42-14	34	....	....
1912	142-11	184	35-12	62	20- 9	27	28- 3	35	19- 2	22	15- 8	16	11- 2	11	12- 7	11	1.00	....
1913	94-15	124	27- 9	44	22- 3	29	18-11	23	15- 3	17	7- 1	7	4- 4	4	0- 0	0	1.33	....
1914	63-10	93	40- 4	64	15- 9	20	3- 5	4	3- 9	4	0-15	1	0- 0	0	0- 0	0	7.00	....
1915	39- 0	42	4- 8	6	3-15	5	11- 8	13	7-14	8	5- 2	5	1- 1	1	5- 0	4	5.33	....
Average	104.9	128	25.9	42	15.5	20	16.3	20	15.0	17	12.4	13	7.5	7	12.2	10	3.67	....
Standard grade—																		
1910	73-25	103	23-13	39	19- 7	27	11-11	15	9-10	11	8- 0	9	2- 0	2	0- 0	0	....	....
1911	89- 3	92	9-10	14	4-14	6	15- 0	17	9- 7	10	10- 4	10	14-11	14	25- 5	21	....	....
1912	91-10	128	41-10	68	13- 6	18	20-13	25	7-14	9	5-13	6	0- 0	0	2- 2	2	1.50	....
1913	46-14	63	19- 5	31	7- 9	10	9-12	11	7- 4	8	2- 0	2	1- 0	1	0- 0	0	2.67	....
1914	46- 9	70	33- 8	54	8- 0	10	4- 2	5	0-15	1	0- 0	0	0- 0	0	0- 0	0	6.33	....
1915	23- 3	26	6- 2	8	3- 6	4	4- 6	5	4- 0	4	4- 3	4	1- 2	1	0- 0	0	6.50	....
Average	62.0	80	22.3	35	9.5	13	11.0	13	6.5	7	5.0	5	3.1	3	4.6	4	4.25	....
Cull fruits—																		
1912	2- 8	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	9- 5	33	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	6-14	17	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.33	....
1915	1-11	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.00	....
Average	5.1	15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.17	....
Total crop—																		
1910	215- 9	282	59-11	96	41- 1	56	35-12	45	33- 0	38	23- 4	25	9-12	10	13- 1	12	....	....
1911	237- 5	238	21- 6	30	14- 0	17	27- 4	31	30- 5	32	40-12	40	35- 7	33	68- 3	55	....	....
1912	236-13	317	77- 6	130	33-15	45	49- 0	60	27- 0	31	21- 5	22	11- 2	11	14- 9	13	1.33	0
1913	151- 2	220	46-14	75	29-12	39	28- 7	34	22- 7	25	9- 1	9	5- 4	5	0- 0	0	2.00	1
1914	117- 1	180	73-12	118	23- 9	30	7- 7	9	4- 8	5	0-15	1	0- 0	0	0- 0	0	5.56	0
1915	63-14	71	10-10	14	7- 5	9	15-14	18	11-14	12	9- 5	9	2- 3	2	5- 0	4	5.00	1
Average	**170.3**	**218**	**48.3**	**77**	**24.9**	**33**	**27.3**	**33**	**21.5**	**24**	**17.4**	**18**	**10.6**	**10**	**16.8**	**14**	**3.47**	**0.50**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
18. Tree No. 23-62-22, Alternate-Bearing strain: Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	140–12	209	83–11	136	20– 9	28	17– 5	22	14– 3	17	4– 1	5	0–14	1	0– 0	0	......	......
1911	112–13	96	7– 3	11	2– 7	3	2–11	3	6– 0	6	7– 5	7	12– 1	11	75– 2	55	......	......
1912	174– 5	214	29–14	49	22– 9	31	25– 9	32	30–14	36	25– 5	28	18–12	19	21– 6	19	3.00	......
1913	100–13	120	18– 2	27	22– 5	28	23– 6	27	16–13	18	15– 9	16	1– 2	1	3– 8	3	3.00	......
1914	61–14	87	29– 8	46	15– 9	20	12– 6	16	4– 7	5	0– 0	0	0– 0	0	0– 0	0	5.00	......
1915	64– 9	72	14–12	20	14– 9	17	11– 0	12	13– 0	13	6– 6	6	1– 3	1	3–11	3	6.67	......
Average	109.2	133	30.6	48	16.3	21	15.4	19	14.2	16	9.8	10	5.7	5	17.3	13	4.42	......
Standard grade—																		
1910	35–14	60	24– 1	42	3– 1	5	3– 5	5	4– 5	6	1– 2	2	0– 0	0	0– 0	0	......	......
1911	45–12	48	9–15	15	4– 6	5	5–12	6	7–13	8	0– 0	0	4–10	4	13– 4	10	......	......
1912	85– 3	106	20– 4	34	8– 5	11	14– 7	18	13– 5	15	9– 7	10	7–15	8	11–18	10	2.83	......
1913	47– 1	60	15–14	25	10– 7	13	5– 2	6	8– 3	9	5– 3	5	1– 2	1	1– 2	1	.67	......
1914	58– 1	91	44– 2	73	7– 8	10	6– 7	8	0– 0	0	0– 0	0	0– 0	0	0– 0	0	4.00	......
1915	43–15	49	13–12	18	6– 0	7	10– 7	11	7– 0	7	3– 3	3	2– 5	2	1– 4	1	5.67	......
Average	52.6	69	21.3	35	6.6	9	7.6	9	6.8	7	3.1	4	2.6	3	4.5	4	3.29	......
Cull fruits—																		
1912	5– 2	6	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1913	3– 3	20	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1914	15– 4	27	......	......	......	......	......	......	......	......	......	......	......	......	......	......	5.67	......
1915	3–13	7	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.33	......
Average	6.9	15	......	......	......	......	......	......	......	......	......	......	......	......	......	......	5.00	......

Total crop—																		
1910	176–10	269	107–13	178	23–10	33	20–10	27	18– 8	23	5– 3	7	0–14	1	0– 0	0	....	....
1911	158– 9	144	17– 2	26	6–13	8	8– 7	9	13–13	14	7– 5	7	16–11	15	88– 6	65	....	....
1912	264–10	326	50– 2	83	30–14	42	40– 0	50	44– 3	51	34–12	38	26–11	27	32–14	29	2.89	0
1913	151– 1	200	34– 0	52	32–12	41	28– 8	33	25– 0	27	20–12	21	2– 4	2	4–10	4	1.83	0
1914	135– 3	205	73–10	119	23– 1	30	18–13	24	4– 7	5	0– 0	0	0– 0	0	0– 0	0	4.89	3
1915	112– 5	128	28– 8	38	20– 9	24	21– 7	23	20– 0	20	9– 9	9	3– 8	3	4–15	4	5.56	2
Average	**166.4**	**212**	**51.9**	**83**	**22.9**	**30**	**23.0**	**28**	**21.0**	**23**	**12.9**	**14**	**8.8**	**8**	**21.8**	**17**	**3.79**	**1.25**
19. Tree No. 23–61–18, Alternate-Bearing strain: Ivory-White grade—																		
1910	96– 4	130	35– 4	55	13–11	19	18– 1	23	14– 5	17	10–11	12	2– 0	2	2– 4	2	....	....
1911	61–14	46	0–14	2	0–11	1	5– 4	6	2–13	3	0– 0	0	4– 6	4	47–14	30	....	....
1912	189– 5	258	82– 2	131	31– 4	41	26– 3	32	21–13	25	20–12	22	4– 1	4	3– 2	3	2.33	....
1913	91– 9	99	9– 3	13	9–12	12	20– 0	23	19– 8	21	13– 8	13	9–12	9	9–14	8	.33	....
1914	51– 1	72	28– 4	44	12– 2	16	6– 1	7	4–10	5	0– 0	0	0– 0	0	0– 0	0	5.33	....
1915	81– 2	90	20–13	29	13–12	16	12– 0	13	10– 2	10	13– 9	13	6–13	6	4– 1	3	4.00	....
Average	95.2	116	29.4	46	13.5	18	14.6	17	12.2	13	9.8	10	4.5	4	11.2	8	3.00	....
Standard grade—																		
1910	81–15	119	36– 2	59	9– 7	14	16– 1	21	13–11	17	6–10	8	0– 0	0	0– 0	0	....	....
1911	37– 2	31	4– 4	6	0–14	1	0–13	1	4–13	5	0– 0	0	4– 8	4	21–14	14	....	....
1912	95–10	128	41–14	65	12– 5	16	18– 3	22	13– 3	15	4–13	5	3– 0	3	2– 4	2	4.00	....
1913	67– 3	82	15–10	27	10– 3	13	8–12	10	13– 5	14	10– 5	10	4– 6	4	4–10	4	2.00	....
1914	48–13	69	30– 2	46	12–10	16	4– 4	5	1–13	2	0– 0	0	0– 0	0	0– 0	0	5.33	....
1915	32–13	36	7– 9	11	3– 6	4	6– 7	7	4–14	5	5– 7	5	2– 7	2	2–11	2	4.67	....
Average	60.6	78	22.6	35	8.2	10	9.1	11	8.6	10	4.5	5	2.4	2	5.2	3	4.00	....
Cull fruits—																		
1912	9– 6	16	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	12– 5	54	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	17– 2	41	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.67	....
1915	3–14	8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.00	....
Average	10.7	29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.84	....
Total crop—																		
1910	178– 3	249	71– 6	114	23– 2	33	34– 2	44	28– 0	34	17– 5	20	2– 0	2	2– 4	2	....	....
1911	99– 0	77	5– 2	8	1– 9	2	6– 1	7	7–10	8	0– 0	0	8–14	8	69–12	44	....	....
1912	294– 5	402	124– 0	196	43– 9	57	44– 6	54	35– 0	40	25– 9	27	7– 1	7	5– 6	5	3.44	0
1913	171– 1	235	24–13	40	19–15	25	28–12	33	32–13	35	23–13	23	14– 2	13	14– 8	12	1.17	0
1914	117– 0	182	58– 6	90	24–12	32	10– 5	12	6– 7	7	0– 0	0	0– 0	0	0– 0	0	5.44	1
1915	117–13	134	28– 6	40	17– 2	20	18– 7	20	15– 0	15	19– 0	18	9– 4	8	6–12	5	4.00	1
Average	**162.9**	**213**	**52.0**	**81**	**21.7**	**28**	**23.7**	**28**	**20.8**	**23**	**14.3**	**15**	**6.9**	**6**	**16.4**	**11**	**3.51**	**0.50**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
20. Tree No. 23-60-10, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	96– 3	131	33–12	53	15–15	22	23–13	30	12–11	15	4– 2	5	2– 0	2	3–14	4	....	....
1911	159– 5	152	7– 8	10	4–14	6	18– 8	21	17– 9	19	14– 6	14	36– 4	33	60– 4	49	....	....
1912	185– 0	216	27– 7	42	24–15	32	33– 5	40	23–14	27	23–12	25	24– 7	24	27– 4	26	4.67	....
1913	94–11	102	8– 4	14	8– 8	11	8– 4	10	16–11	18	16–13	17	11– 0	10	25– 3	22	3.00	....
1914	55– 5	74	26–11	41	8–11	11	5–13	7	7–14	8	6–14	7	0– 0	0	0– 0	0	6.00	....
1915	42– 4	43	8– 8	11	2–10	3	4–10	5	6–12	7	6– 9	6	6–15	6	6– 4	5	3.67	....
Average	105.5	120	18.7	29	10.9	14	15.7	19	14.2	16	12.1	12	13.4	12	20.5	18	4.34	....
Standard grade—																		
1910	99– 8	150	49–13	84	17–10	25	17– 1	23	10– 8	13	2– 9	3	1–15	2	0– 0	0	....	....
1911	61–14	66	5– 5	8	3– 0	4	13– 6	15	7– 0	8	6–14	7	11– 6	11	14–15	13	....	....
1912	39– 9	50	12–10	19	4– 8	6	7– 7	9	9– 1	10	2–15	3	0–14	1	2– 2	2	2.33	....
1913	33– 0	50	12– 8	28	3– 3	4	6– 1	7	3– 9	4	2–15	3	2– 4	2	2– 8	2	3.33	....
1914	48–15	64	18– 1	29	8– 1	10	8–11	10	12– 1	13	0–15	1	1– 2	1	0– 0	0	4.33	....
1915	26– 7	28	3– 0	4	2– 8	3	7– 8	8	4–11	5	3– 3	3	4– 7	4	1– 2	1	3.67	....
Average	51.6	68	16.9	28	6.5	9	10.0	12	7.7	9	3.2	4	3.7	4	3.4	3	3.42	....
Cull fruits—																		
1912	2– 3	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....		....
1913	8– 5	26	....	....	....	....	....	....	....	....	....	....	....	....	....	....		....
1914	10– 4	17	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.67	....
1915	7– 4	10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.67	....
Average	7.0	14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.67	....

Total crop—																		
1910	195–11	281	83– 9	137	33– 9	47	40–14	53	23– 3	28	6–11	8	3–15	4	3–14	4	....	....
1911	221– 3	218	12–13	18	7–14	10	31–14	36	24– 9	27	21– 4	21	47–10	44	75– 3	62	....	....
1912	226–12	269	40– 1	61	29– 7	38	40–12	49	32–15	37	26–11	28	25– 5	25	29– 6	28	3.11	0
1913	136– 0	178	20–12	42	11–11	15	14– 5	17	20– 4	22	19–12	20	13– 4	12	27–11	24	3.17	0
1914	114– 8	155	44–12	70	16–12	21	14– 8	17	19– 5	21	7–13	8	1– 2	1	0– 0	0	4.67	2
1915	75–15	81	11– 8	15	5– 2	6	12– 2	13	11– 7	12	9–12	9	11– 6	10	7– 6	6	4.33	0
Average	**161.7**	**197**	**35.6**	**57**	**17.4**	**23**	**25.7**	**31**	**21.9**	**25**	**15.3**	**16**	**17.1**	**16**	**23.9**	**21**	**2.55**	**0.50**
21. Tree No. 23-59-8, Marsh strain:																		
Ivory-White grade—																		
1910	112–14	149	35– 8	56	19–15	27	21– 5	27	18– 6	21	7– 3	8	3–12	4	6– 3	6	....	....
1911	197–12	173	4–15	7	0–14	1	11–14	13	17–10	18	20– 6	19	37– 4	34	104– 3	81	....	....
1912	203– 7	243	41– 9	65	24–15	33	31– 8	38	32– 4	36	31– 1	32	18– 6	18	23–12	21	2.00	....
1913	126– 6	143	17– 6	27	12– 5	16	20– 4	24	23– 6	26	14–11	15	18–12	18	19–10	17	.33	....
1914	45– 1	60	19– 8	30	8– 6	11	6–10	8	5–10	6	2–12	3	2– 3	2	0– 0	0	4.33	....
1915	15–11	16	1– 8	2	0–14	1	3–12	4	3–13	4	1– 0	1	2– 5	2	2– 7	2	4.33	....
Average	116.9	131	20.1	31	11.2	15	15.9	19	16.9	19	12.8	13	13.8	13	26.0	21	2.75	....
Standard grade—																		
1910	58–15	86	19–10	34	12–15	19	12– 8	17	5– 9	7	5– 5	6	1–15	2	1– 1	1	....	....
1911	43– 7	45	6–15	11	4– 4	5	4– 7	5	5–14	6	4– 4	4	2– 4	2	15– 7	12	....	....
1912	48– 3	62	20–11	32	3–15	5	6–10	8	7– 5	8	5– 2	5	2– 2	2	2– 6	2	4.83	....
1913	30– 9	38	5–15	11	4–10	6	4– 4	5	6– 7	7	4–14	5	2– 3	2	2– 4	2	1.00	....
1914	41–15	61	29–12	46	7–12	10	1–12	2	1–12	2	0–15	1	0– 0	0	0– 0	0	6.67	....
1915	19– 4	20	1– 4	2	2–11	3	4– 9	5	3–14	4	3– 4	3	1– 2	1	2– 8	2	6.00	....
Average	40.4	52	14.0	23	6.0	8	5.7	7	5.1	5	4.0	4	1.7	2	4.0	3	4.63	....
Cull fruits—																		
1912	2–13	6																
1913	7– 5	27	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	12– 6	28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.67	....
1915	3– 9	6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.67	....
Average	6.5	17	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.67	....
Total crop—																		
1910	171– 3	235	55– 2	90	32–14	46	33–13	44	23–15	28	12– 8	14	5–11	6	7– 4	7	....	....
1911	241 3	218	11–14	18	5– 2	6	16– 5	18	23– 8	24	24–10	23	40– 2	36	119–10	93	....	....
1912	254– 7	311	62– 4	97	28–14	38	38– 2	46	39– 9	44	36– 3	37	20– 8	20	26– 2	23	3.89	2
1913	164– 4	208	23– 5	38	16–15	22	24– 8	29	29–13	33	19– 9	20	20–15	20	21–14	19	.67	0
1914	99– 6	149	49– 4	76	16– 2	21	8– 6	10	7– 6	8	3–11	4	2– 3	2	0– 0	0	4.89	0
1915	38– 0	42	2–12	4	3– 9	4	8– 5	9	7–11	8	4– 4	4	3– 7	3	4–15	4	4.67	4
Average	**161.5**	**194**	**34.1**	**54**	**17.2**	**23**	**21.6**	**26**	**22.0**	**24**	**16.8**	**17**	**15.5**	**15**	**30.0**	**24**	**3.53**	**1.50**

TABLE III.—*Detailed statement of the annual performane of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
22. Tree No. 23-61-14, Alternate-Bearing strain: Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	120–15	154	29– 6	46	18–14	25	26–15	33	17– 3	20	11– 2	12	13–11	14	3–12	4	....	....
1911	243– 2	251	18– 8	28	17– 8	22	30– 3	35	31–10	34	39– 0	39	34– 4	33	72– 1	60	....	....
1912	105– 0	102	2– 9	4	5– 5	7	7– 6	9	11–13	13	16– 9	17	15–14	15	45– 8	37	1.67	....
1913	148– 0	172	26–11	41	14–11	19	23– 8	28	36–14	41	18– 2	18	10–10	10	17– 8	15	0	....
1914	26– 5	35	14–13	22	3– 4	4	4– 6	5	1–13	2	2– 1	2	0– 0	0	0– 0	0	6.67	....
1915	69–15	78	16– 2	22	8– 6	11	11–14	13	14–12	15	10–10	10	4– 9	4	3–10	3	5.33	....
Average	118.9	132	18.0	27	11.3	15	17.4	21	19.0	21	16.3	16	13.2	13	23.7	20	3.42	....
Standard grade—																		
1910	67– 0	102	32–10	54	4–11	8	11– 3	16	6– 5	9	6– 1	8	4– 2	5	2– 0	2	....	....
1911	40– 8	47	6– 0	11	3–12	5	2–10	3	7– 6	8	6–12	7	3–14	4	10– 2	9	....	....
1912	17–11	19	1– 4	2	1– 8	2	3– 8	4	2–10	3	1–15	2	0– 0	0	6–14	6	.83	....
1913	33–14	53	16–15	34	2– 5	3	2– 9	3	8– 3	9	2–14	3	1– 0	1	0– 0	0	.50	....
1914	29– 0	43	23– 1	36	2– 8	3	2– 9	3	0–14	1	0– 0	0	0– 0	0	0– 0	0	6.67	....
1915	36–14	42	8– 0	12	8– 8	10	6– 5	7	4–14	5	4– 6	4	3– 8	3	1– 5	1	6.67	....
Average	37.5	51	14.7	25	3.9	5	4.8	6	5.0	6	3.6	4	2.1	2	3.4	3	3.67	....
Cull fruits—																		
1912	2– 5	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	8–14	42	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	4–15	11	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.33	....
1915	4– 8	7	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.00	....
Average	5.2	16	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.17	....

Total crop—																		
1910	187–15	256	62–0	100	23–9	33	38–2	49	23–8	29	17–3	20	17–13	19	5–12	6	....	....
1911	283–10	298	24–8	39	21–4	27	32–13	38	39–0	42	45–12	46	38–2	37	82–3	69	....	....
1912	125–0	125	3–13	6	6–13	9	10–14	13	14–7	16	18–8	19	15–14	15	52–6	43	1.33	1
1913	190–12	267	43–10	75	17–0	22	26–1	31	45–1	50	21–0	21	11–10	11	17–8	15	.20	0
1914	60–4	89	37–14	58	5–12	7	6–15	8	2–11	3	2–1	2	0–0	0	0–0	0	5.89	1
1915	111–5	127	24–2	34	16–14	21	18–3	20	19–10	20	15–0	14	8–1	7	4–15	4	5.33	5
Average	**159.8**	**194**	**32.7**	**52**	**15.2**	**20**	**22.2**	**27**	**24.1**	**27**	**19.9**	**20**	**15.8**	**15**	**27.1**	**23**	**3.19**	**1.75**
23. Tree No. 23-62-21, Marsh strain:																		
Ivory-White grade—																		
1910	79–2	87	10–11	17	8–6	11	8–15	11	7–13	9	7–3	8	5–13	6	30–5	25	....	....
1911	119–13	112	7–2	10	3–4	4	11–13	13	2–13	4	12–5	12	25–2	24	57–6	45	....	....
1912	160–14	185	20–12	36	8–1	11	25–0	31	26–4	30	16–11	18	23–3	23	40–15	36	0	....
1913	113–14	131	18–8	27	18–13	24	15–4	18	23–9	26	17–14	18	10–8	10	9–6	8	.33	....
1914	88–7	129	59–4	94	16–11	21	7–10	9	4–14	5	0–0	0	0–0	0	0–0	0	3.67	....
1915	65–8	71	13–15	19	10–5	12	9–3	10	7–10	8	10–9	10	6–10	6	7–4	6	4.00	....
Average	104.6	119	21.7	34	10.9	14	13.0	15	12.2	14	10.8	11	11.9	12	24.2	20	2.00	....
Standard grade—																		
1910	25–13	36	7–14	14	2–13	4	2–15	4	3–8	5	0–13	1	4–8	5	3–6	3	....	....
1911	34–10	37	7–13	11	4–3	5	5–7	6	2–15	3	0–0	0	5–5	5	8–15	7	....	....
1912	70–9	77	5–11	10	6–14	9	4–13	6	8–13	10	12–5	13	8–2	8	23–15	21	.33	....
1913	53–10	66	15–14	25	6–8	8	7–4	9	9–15	11	4–13	5	2–4	2	7–0	6	1.67	....
1914	57–14	87	37–3	62	11–6	15	5–4	6	0–15	1	3–2	3	0–0	0	0–0	0	4.00	....
1915	58–9	66	15–11	22	9–9	11	11–0	12	11–6	11	8–10	8	1–2	1	1–3	1	5.67	....
Average	50.2	62	15.0	24	6.9	9	6.1	8	6.2	7	4.9	5	3.5	3	7.4	6	2.92	....
Cull fruits—																		
1912	4–0	7	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	7–2	43	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	14–2	33	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.67	....
1915	5–2	8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.33	....
Average	7.6	23	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.50	....
Total crop—																		
1910	104–15	123	18–9	31	11–3	15	11–14	15	11–5	14	8–0	9	10–5	11	33–11	28	....	....
1911	154–7	149	14–15	21	7–7	9	17–4	19	5–12	7	12–5	12	30–7	29	66–5	52	....	....
1912	235–7	269	26–7	46	14–15	20	29–13	37	35–1	40	29–0	31	31–5	31	64–14	57	.22	0
1913	174–10	240	34–6	52	25–5	32	22–8	27	33–8	37	22–11	23	12–12	12	16–6	14	1.00	1
1914	160–7	249	96–7	156	28–1	36	12–14	15	5–13	6	3–2	3	0–0	0	0–0	0	3.78	1
1915	129–3	145	29–10	41	19–14	23	20–3	22	19–0	19	19–3	18	7–12	7	8–7	7	4.33	4
Average	**159.8**	**196**	**36.7**	**58**	**17.8**	**23**	**19.1**	**23**	**18.4**	**21**	**15.7**	**16**	**15.4**	**15**	**31.6**	**26**	**2.33**	**1.50**

TABLE III.—*Detailed statement of the annual performance of Mash grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
24. Tree No. 23-59-14, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	110- 2	124	14- 4	23	6- 9	9	6- 3	8	18-13	22	16- 7	18	18- 4	18	29-10	26	....	....
1911	159-13	144	14- 1	19	9- 6	11	10- 2	11	9-14	10	8- 3	8	21- 3	19	87- 0	66	....	....
1912	117- 4	144	24-13	41	9-12	13	13- 7	17	21-13	25	20- 8	22	12- 7	13	14- 8	13	0.67	....
1913	164- 8	194	26-11	41	27- 0	35	27-14	33	30-10	34	24-14	26	10- 3	10	17- 4	15	0	....
1914	56- 1	77	26-11	41	14- 9	19	8- 7	10	5- 8	6	0-14	1	0- 0	0	0- 0	0	5.00	....
1915	22-13	22	0-13	1	3-10	4	3-12	4	3- 2	3	5- 7	5	2- 6	2	3-11	3	4.00	....
Average	105.1	118	17.9	28	11.8	15	11.6	14	15.0	17	12.7	13	10.8	10	25.3	21	2.42	....
Standard grade—																		
1910	44-10	56	5- 2	9	3-14	6	2-10	4	9-12	12	11-12	13	4- 5	5	7- 3	7	....	....
1911	38-11	48	9-13	17	6-11	8	2-10	3	3-11	5	0-15	1	3- 3	4	11-12	10	....	....
1912	97- 1	118	13- 2	21	9-12	13	27- 6	34	16- 3	19	9- 6	10	13- 9	14	7-11	7	.50	....
1913	51-15	65	12- 2	21	6-15	9	8- 5	10	12- 2	13	4-12	5	3- 5	3	4- 6	4	1.33	....
1914	47-10	68	26- 0	42	10- 0	13	4- 4	5	5- 8	6	1-14	2	0- 0	0	0- 0	0	4.33	....
1915	21-11	22	2- 8	4	4- 7	5	1-14	2	4- 4	4	3- 5	3	1- 4	1	4- 1	3	2.33	....
Average	50.2	63	11.4	19	7.0	9	7.9	10	8.5	10	5.2	6	4.2	5	5.9	5	2.12	....
Cull fruits—																		
1912	2- 1	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	7- 8	17	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	14-12	31	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.00	....
1915	2-11	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.50	....
Average	6.7	14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.12	....

Total crop—																		
1910	154–12	180	19– 6	32	10– 7	15	8–13	12	28– 9	34	28– 3	31	22– 9	23	36–13	33	....	....
1911	198– 8	192	23–14	36	16– 1	19	12–12	14	13– 9	15	9– 2	9	24– 6	23	98–12	76	....	....
1912	215– 6	265	37–15	62	19– 8	26	40–13	51	38– 0	44	28–14	32	26– 0	27	22– 3	20	.56	0
1913	223–15	276	38–13	62	33–15	44	36– 3	43	42–12	47	29–10	31	13– 8	13	21–10	19	.67	1
1914	118– 7	176	52–11	83	24– 9	32	12–11	15	11– 0	12	2–12	3	0– 0	0	0– 0	0	4.11	0
1915	47– 3	48	3– 5	5	8– 1	9	5–10	6	7– 6	7	8–12	8	3–10	3	7–12	6	3.75	2
Average	**159.7**	**190**	**29.3**	**47**	**18.8**	**24**	**19.5**	**24**	**23.5**	**27**	**17.9**	**19**	**15.0**	**15**	**31.2**	**26**	**2.25**	**0.75**
25. Tree No. 23-62-15, Alternate-Bearing strain: Ivory-White grade—																		
1910	146– 2	194	51–14	78	24– 8	33	36– 4	45	23– 2	27	7– 0	8	0– 0	0	3– 6	3	....	....
1911	171–10	131	2– 7	4	0– 0	0	5– 6	6	8–15	9	13–11	13	9–10	9	131– 9	90	....	....
1912	173– 8	213	48– 3	74	23– 8	30	31–13	38	17– 4	19	26–12	28	14– 8	14	11– 8	10	2.00	....
1913	85– 5	95	9–11	15	15–10	20	11–12	14	12– 2	13	7– 2	7	17– 2	16	11–14	10	.67	....
1914	51– 2	74	31–10	50	10– 1	13	4– 2	5	4– 6	5	0–15	1	0– 0	0	0– 0	0	7.33	....
1915	60–12	64	8– 4	12	5– 2	6	8– 2	9	15– 0	15	13–13	13	7–15	7	2– 8	2	4.33	....
Average	114.7	129	25.3	39	13.1	17	16.3	20	13.5	15	11.6	12	8.2	8	26.8	19	2.39	....
Standard grade—																		
1910	53– 9	82	23– 4	41	5– 1	8	8–15	13	10– 5	13	1–14	2	4– 2	5	0– 0	0	....	....
1911	23– 7	21	0– 0	0	0– 0	0	2– 6	3	2–13	3	1–13	2	4– 2	4	12– 5	9	....	....
1912	66– 9	91	29– 7	47	13–11	18	6– 8	8	8–14	10	5– 0	5	1–15	2	1– 2	1	2.20	....
1913	16– 3	24	5– 5	12	1– 8	2	2– 6	3	3– 9	4	1– 1	1	1– 3	1	1– 3	1	3.67	....
1914	41–12	65	28–13	49	6– 2	8	5– 0	6	1–13	2	0– 0	0	0– 0	0	0– 0	0	5.33	....
1915	24– 4	27	5– 0	8	2–10	3	2–14	3	6– 0	6	4– 4	4	2– 4	2	1– 4	1	5.33	....
Average	37.6	51	15.3	26	4.9	7	4.7	6	5.5	6	2.3	2	2.3	2	2.6	2	4.13	....
Cull fruits—																		
1912	11–12	21	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	7– 2	23	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	13– 6	31	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.67	....
1915	2– 3	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.33	....
Average	8.6	20	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.00	....
Total crop—																		
1910	199–11	276	75– 2	119	29– 9	41	45– 3	58	33– 7	40	8–14	10	4– 2	5	3– 6	3	....	....
1911	195– 1	152	2– 7	4	0– 0	0	7–12	9	11–12	12	15– 8	15	13–12	13	143–14	99	....	....
1912	251–13	325	77–10	121	37– 3	48	38– 5	46	26– 2	29	31–12	33	16– 7	16	12–10	11	2.13	0
1913	108–10	142	15– 0	27	17– 2	22	14– 2	17	15–11	17	8– 3	8	18– 5	17	13– 1	11	2.17	0
1914	106– 4	170	60– 7	99	16– 3	21	9– 2	11	6– 3	7	0–15	1	0– 0	0	0– 0	0	6.11	1
1915	87– 3	94	13– 4	20	7–12	9	11– 0	12	21– 0	21	18– 1	17	10– 3	9	3–12	3	5.33	0
Average	**158.1**	**193**	**40.6**	**65**	**18.0**	**24**	**20.9**	**26**	**19.0**	**21**	**13.9**	**14**	**10.5**	**10**	**29.4**	**21**	**3.94**	**0.25**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
26. Tree No. 23-59-9, Alternate-Bearing strain: Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	130– 4	175	56– 3	84	11–10	16	29–11	37	19–11	23	7–14	9	4– 1	4	1– 2	2	....	....
1911	126– 8	105	0–11	1	1–10	2	7– 0	8	6– 4	6	10– 7	10	24– 0	21	76– 8	57	....	....
1912	193– 1	213	120– 3	123	23–11	32	24–15	31	11–15	14	8– 6	9	2–14	3	1– 1	1	2.67	....
1913	91– 0	102	8–10	14	11–11	15	14–13	17	20– 5	22	12–11	13	10– 8	10	12– 6	11	.33	....
1914	57–14	79	30–15	47	15– 2	19	4– 5	5	6– 8	7	1– 0	1	0– 0	0	0– 0	0	5.33	....
1915	40– 4	46	11–10	17	4– 3	5	6– 4	7	5–14	6	3– 0	3	8– 1	7	1– 4	1	5.67	....
Average	106.5	120	38.1	48	11.3	15	14.5	18	11.8	13	7.2	8	8.3	8	15.4	12	3.50	....
Standard grade—																		
1910	45–11	68	18– 9	32	5–11	9	10–10	14	7– 2	9	2–11	3	1– 0	1	0– 0	0	....	....
1911	30–12	32	1– 6	3	7– 2	8	4–12	5	3– 2	3	4– 1	4	6–12	6	3– 9	3	....	....
1912	69– 6	99	31–12	53	12–10	17	11– 8	14	7–14	9	5–10	6	0– 0	0	0– 0	0	.50	....
1913	38–12	57	14– 4	31	4–12	6	4– 4	5	6–14	7	5– 4	5	1– 0	1	2– 6	2	5.33	....
1914	43– 3	63	31– 6	49	7– 6	9	1–10	2	2–13	3	0– 0	0	0– 0	0	0– 0	0	6.00	....
1915	36–11	42	8– 8	13	5–12	7	9– 6	10	4–14	5	2– 2	2	4–11	4	1– 6	1	4.67	....
Average	44.1	60	17.6	30	7.2	9	7.0	8	5.4	6	3.3	3	2.2	2	1.2	1	4.13	....
Cull fruits—																		
1912	4– 0	11	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	7– 2	30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	11–13	30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.33	....
1915	16– 0	24	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.00	....
Average	9.7	24	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.67	....

Total crop—																		
1910	175–15	243	74–12	116	17– 5	25	40– 5	51	26–13	32	10– 9	12	5– 1	5	1– 2	2	......	......
1911	157– 4	137	2– 1	4	8–12	10	11–12	13	9– 6	9	14– 8	14	30–12	27	80– 1	60	......	......
1912	266– 7	323	151–15	176	36– 5	49	36– 7	45	19–13	23	14– 0	15	2–14	3	1– 1	1	.58	0
1913	136–14	189	22–14	45	16– 7	21	19– 1	22	27– 3	29	17–15	18	11– 8	11	14–12	13	2.83	0
1914	112–14	172	62– 5	96	22– 8	28	5–15	7	9– 5	10	1– 0	1	0– 0	0	0– 0	0	5.22	0
1915	92–15	112	20– 2	30	9–15	12	15–10	17	10–12	11	5– 2	5	12–12	11	2–10	2	4.44	2
Average	**157.1**	**196**	**55.7**	**78**	**18.5**	**24**	**21.5**	**26**	**17.2**	**19**	**10.5**	**11**	**10.5**	**10**	**16.6**	**13**	**3.27**	**0.50**
27. Tree No. 23–59–10, Marsh strain:																		
Ivory-White grade—																		
1910	86–12	68	0– 0	0	0–14	1	0– 0	0	0–15	1	1–13	2	7– 1	7	76– 1	57	......	......
1911	184–11	198	19– 0	26	22– 5	28	29–10	34	29–11	32	28–13	29	22– 5	21	32–15	28	......	......
1912	167– 5	180	10– 3	16	7– 7	10	28–10	35	25– 5	30	17–15	19	21– 4	21	56– 9	49	.67	......
1913	102–14	118	7–14	12	18– 3	23	22– 0	26	26– 2	29	11–10	12	11– 9	11	5– 8	5	1.67	......
1914	62– 2	78	19–10	28	15–15	20	11–14	14	7– 4	8	5– 7	6	2– 0	2	0– 0	0	5.00	......
1915	65– 9	64	4– 2	6	2–10	3	6– 4	7	18–10	19	8– 8	8	12– 9	11	12–14	10	5.00	......
Average	111.6	118	10.1	15	11.2	14	16.4	19	18.0	20	12.4	13	12.8	12	30.7	25	3.09	......
Standard grade—																		
1910	15–10	17	2– 0	3	0– 0	0	0–14	1	1–13	2	0–15	1	3– 8	4	6– 8	6	......	......
1911	56– 5	70	19– 5	29	8–14	11	11– 3	13	7– 5	8	5– 1	5	1– 1	1	3– 8	3	......	......
1912	53– 2	61	5– 1	9	3– 9	5	7– 6	9	8– 2	9	12– 1	13	5– 2	5	11–13	11	1.33	......
1913	38– 2	52	17–12	29	7–14	10	1– 9	2	4– 8	5	3– 2	3	2– 2	2	1– 3	1	5.00	......
1914	47– 6	65	24–11	38	9– 6	12	4– 2	5	3– 7	4	2–11	3	3– 1	3	0– 0	0	3.67	......
1915	25–12	25	2–14	4	1–10	2	3–12	4	6– 3	6	1– 2	1	5–14	5	4– 5	3	3.67	......
Average	39.4	48	12.0	18	5.2	7	4.8	6	5.2	6	4.1	4	3.4	4	4.5	4	3.42	......
Cull fruits—																		
1912	3–13	7	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1913	10– 8	47	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1914	17–13	37	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.67	......
1915	1– 5	2	......	......	......	......	......	......	......	......	......	......	......	......	......	......	5.00	......
Average	8.4	23	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.84	......
Total crop—																		
1910	102– 6	85	2– 0	3	0–14	1	0–14	1	2–12	3	2–12	3	10– 9	11	82– 9	63	......	......
1911	241– 0	268	38– 5	55	31– 3	39	40–13	47	37– 0	40	33–14	34	23– 6	22	36– 7	31	......	......
1912	224– 4	248	15– 4	25	11– 0	15	36– 0	44	33– 7	39	30– 0	32	26– 6	26	68– 6	60	1.11	0
1913	151– 8	217	25–10	41	26– 1	33	23– 9	28	30–10	34	14–12	15	13–11	13	6–11	6	3.33	0
1914	127– 5	180	44– 5	66	25– 5	32	16– 0	19	10–11	12	8– 2	9	5– 1	5	0– 0	0	4.44	2
1915	92–10	91	7– 0	10	4– 4	5	10– 0	11	24–13	25	9–10	9	18– 7	16	17– 3	13	4.50	1
Average	**156.5**	**182**	**22.1**	**33**	**16.4**	**21**	**21.2**	**25**	**23.2**	**26**	**16.5**	**17**	**16.2**	**16**	**35.2**	**29**	**3.35**	**0.75**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
28. Tree No. 23-62-13, Alternate-Bearing strain: Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	130- 6	169	42- 4	64	15- 6	21	30- 7	38	18-11	22	11- 4	12	5-12	6	6-10	6	....	....
1911	142- 7	135	3-13	6	9- 5	11	19- 4	21	12- 7	13	21- 8	21	23-14	22	52- 4	41	....	....
1912	144- 8	174	27- 7	42	12-13	17	29-13	37	29-15	34	19-12	21	10- 2	10	14-10	13	0.33	....
1913	60- 6	70	10- 4	15	8-14	11	13- 6	16	10- 0	11	9- 2	9	4- 5	4	4- 7	4	.33	....
1914	76-14	110	43- 0	68	21-10	28	5-14	7	5- 8	6	0-14	1	0- 0	0	0- 0	0	5.67	....
1915	70-11	76	11- 8	16	5- 4	6	12- 6	14	24-13	25	9-10	9	5-14	5	1- 4	1	6.67	....
Average	104.2	122	23.0	35	12.2	16	18.5	22	16.9	19	12.0	12	8.2	8	13.2	11	3.25	....
Standard grade—																		
1910	52-15	79	23-13	40	4-10	7	12-11	17	7-11	10	3- 2	4	1- 0	1	0- 0	0	....	....
1911	46- 1	47	2-14	4	1- 7	2	6- 4	7	8- 3	9	6-13	7	11-15	11	8- 9	7	....	....
1912	65- 1	82	23- 1	36	3-15	5	9- 1	11	6-14	8	9- 8	10	6-10	6	6-10	6	2.50	....
1913	33-10	42	12- 2	18	7- 6	9	5- 3	6	4- 9	5	3- 2	3	0- 0	0	1- 4	1	6.00	....
1914	39- 3	57	24- 2	38	5-15	8	7- 6	9	1-12	2	0- 0	0	0- 0	0	0- 0	0	6.00	....
1915	31- 6	36	5-14	10	3- 6	4	5- 6	6	10- 2	10	3- 3	3	2- 3	2	1- 4	1	4.67	....
Average	44.7	57	15.4	25	4.5	6	7.7	9	6.5	7	4.3	5	3.7	3	2.9	2	4.79	....
Cull fruits—																		
1912	6- 3	11	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	8- 8	35	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	8- 7	19	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.00	....
1915	3- 2	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.67	....
Average	6.6	18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.35	....

Total crop—																		
1910	183- 5	248	66- 1	104	20- 0	28	43- 2	55	26- 6	32	14- 6	16	6-12	7	6-10	6	....	....
1911	188- 8	182	6-11	10	10-12	13	25- 8	28	20-10	22	28- 5	28	35-13	33	60-13	48	....	....
1912	215-12	267	50- 8	78	16-12	22	38-14	48	36-13	42	29- 4	31	16- 2	13	21- 4	19	1.78	0
1913	102- 8	147	22- 6	33	16- 4	20	18- 9	22	14- 9	16	12- 4	12	4- 5	4	5-11	5	3.17	1
1914	124- 8	186	67- 2	106	27- 9	36	13- 4	16	7- 4	8	0-14	1	0- 0	0	0- 0	0	4.89	1
1915	105- 3	117	17- 6	26	8-10	10	17-12	20	34-15	35	12-13	12	8- 1	7	2- 8	2	5.67	0
Average	**153.8**	**191**	**38.4**	**60**	**16.7**	**22**	**26.2**	**31**	**23.4**	**26**	**16.3**	**17**	**11.9**	**11**	**16.1**	**13**	**3.88**	**0.50**
29. Tree No. 23-61-15, Marsh strain:																		
Ivory-White grade—																		
1910	126- 6	128	5- 5	8	4- 5	6	12- 2	15	21- 7	23	18- 1	19	12- 4	12	52-14	45	....	....
1911	226-10	249	21- 0	31	22-10	29	46-12	54	42- 3	45	34-12	35	30- 0	29	29- 5	26	....	....
1912	122-13	118	3-15	6	2- 4	3	6- 9	8	15- 4	17	17- 3	18	17- 7	17	60- 3	49	0	....
1913	97- 9	119	20- 0	31	19- 7	25	13- 7	16	15-12	18	19- 5	20	6- 4	6	3- 6	3	1.33	....
1914	32-13	46	18- 7	29	7- 2	9	3- 9	4	2-12	3	0-15	1	0- 0	0	0- 0	0	7.00	....
1915	78- 9	89	19-13	28	11- 0	13	15- 4	17	13-14	14	12-14	12	3- 5	3	2- 7	2	6.00	....
Average	114.1	125	14.8	22	11.1	14	16.3	19	18.5	20	17.2	17	11.5	11	24.7	21	3.58	....
Standard grade—																		
1910	38- 0	47	2-15	5	3- 2	5	5-12	8	6-15	9	5- 1	6	4- 4	5	9-15	9	....	....
1911	36- 8	45	7- 1	14	4- 2	5	4- 3	5	3-10	4	5-11	6	4- 1	4	7-12	7	....	....
1912	25-10	26	2- 2	3	0- 0	0	0-13	1	7- 2	8	2- 1	2	3- 3	3	10- 5	9	.67	....
1913	38- 1	49	12-12	21	4-11	6	5-15	7	6-10	7	5-15	6	1- 0	1	1- 2	1	4.00	....
1914	38- 6	58	26- 1	43	10- 8	13	0-14	1	0-15	1	0- 0	0	0- 0	0	0- 0	0	4.00	....
1915	28- 1	34	9- 5	14	4- 4	5	7- 4	8	3-15	4	1- 0	1	1- 1	1	1- 4	1	5.33	....
Average	34.1	43	10.0	17	4.5	6	4.1	5	4.9	6	3.3	4	2.3	3	5.1	4	3.50	....
Cull fruits—																		
1912	2- 7	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	10-10	40	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	13- 3	27	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.00	....
1915	0- 9	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	8.00	....
Average	6.7	18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.00	....
Total crop—																		
1910	164- 6	175	8- 4	13	7- 7	11	17-14	23	28- 6	32	23- 2	25	16- 8	17	62-13	54	....	....
1911	263- 2	294	28- 1	45	26-12	34	50-15	59	45-13	49	40- 7	41	34- 1	33	37- 1	33	....	....
1912	150-14	147	6- 1	9	2- 4	3	7- 6	9	22- 6	25	19- 4	20	20-10	20	70- 8	58	.44	0
1913	146- 4	208	32-12	52	24- 2	31	19- 6	23	22- 6	25	25- 4	26	7- 4	7	4- 8	4	2.67	0
1914	84- 6	131	44- 8	72	17-10	22	4- 7	5	3-11	4	0-15	1	0- 0	0	0- 0	0	4.56	0
1915	107- 3	124	29- 2	42	15- 4	18	22- 8	25	17-13	18	13-14	13	4- 6	4	3-11	3	6.00	0
Average	**152.7**	**180**	**24.8**	**39**	**15.6**	**20**	**20.4**	**24**	**23.4**	**26**	**20.5**	**21**	**13.8**	**14**	**29.8**	**25**	**3.42**	**0**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
30. Tree No. 23-62-17, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	100– 0	133	33– 5	51	21–10	29	13–15	18	15–11	19	8– 1	9	7– 6	7	0– 0	0	....	....
1911	96– 6	68	0– 0	0– 0	0– 0	0	0–15	1	7– 4	7	4– 4	4	4–13	4	79– 2	52	....	....
1912	135– 1	181	48– 0	76	24– 6	33	22– 8	28	18– 7	21	13–11	15	4–15	5	3– 2	3	1.67	....
1913	89–15	92	3– 5	5	3– 1	4	10– 0	12	20– 4	22	17– 0	17	13–13	13	22– 8	19	3.33	....
1914	38– 2	53	19– 8	31	7–12	10	5– 2	6	3–10	4	1– 0	1	1– 2	1	0– 0	0	4.00	....
1915	107– 9	116	24– 7	33	8– 8	10	21–15	24	20–12	21	19– 4	18	3– 8	3	9– 3	7	4.00	....
Average	94.5	107	21.4	33	10.9	14	12.4	15	14.3	16	10.5	11	5.9	5	19.0	14	3.25	....
Standard grade—																		
1910	80–10	121	46–13	76	10– 8	15	12–12	17	5–15	8	3–10	4	1– 0	1	0– 0	0	....	....
1911	23–11	19	0– 0	0	0– 0	0	1– 0	1	1– 2	1	4– 6	4	4– 8	4	12–11	9	....	....
1912	97– 3	134	41– 5	66	19– 6	26	17–15	22	11– 8	13	2–14	3	2– 2	2	2– 1	2	2.17	....
1913	32–10	35	1– 1	2	6– 7	8	2– 5	3	8– 2	9	6– 2	6	2– 3	2	6– 6	5	3.00	....
1914	33– 0	53	27– 1	46	3– 1	4	0– 0	0	2–14	3	0– 0	0	0– 0	0	0– 0	0	5.33	....
1915	34–13	38	7–12	11	4– 2	5	9– 7	10	2–14	3	4– 6	4	2– 7	2	3–13	3	6.33	....
Average	50.3	67	20.7	33	7.2	10	7.2	9	5.4	6	3.6	3	2.1	2	4.2	3	4.21	....
Cull fruits—																		
1912	12– 5	22	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	10– 3	38	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	16–14	36	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.00	....
1915	1– 5	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.50	....
Average	10.2	25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.75	....

1910	180–10	254	80– 2	127	32– 2	44	26–11	35	21–10	27	11–11	13	8– 6	8	0– 0	0	....	....
1911	120– 1	87	0– 0	0	0– 0	0	1–15	2	8– 6	8	8–10	8	9– 5	8	91–13	61	....	....
1912	244– 9	337	89– 5	142	43–12	59	40– 7	50	29–15	34	16– 9	18	7– 1	7	5– 3	5	2.00	0
1913	132–12	165	4– 6	7	9– 8	12	12– 5	15	28– 6	31	23– 2	23	16– 0	15	28–14	24	3.17	0
1914	88– 0	142	46– 9	77	10–13	14	5– 2	6	6– 8	7	1– 0	1	1– 2	1	0– 0	0	5.11	1
1915	143–11	156	32– 3	44	12–10	15	31– 6	34	23–10	24	23–10	22	5–15	5	13– 0	10	4.75	3
Average	**151.6**	**190**	**42.1**	**66**	**18.1**	**24**	**19.6**	**24**	**19.7**	**22**	**14.1**	**14**	**8.0**	**7**	**23.1**	**17**	**3.78**	**1 00**
31. Tree No. 23-61-19, Alternate-Bearing strain: Ivory-White grade—																		
1910	95–12	130	40–15	62	10–14	15	22– 2	28	13–10	16	5– 2	6	3– 1	3	0– 0	0	....	....
1911	68– 6	50	0– 0	0	0– 0	0	8–12	9	6– 4	6	4– 9	4	2– 5	2	46– 8	29	....	....
1912	160– 0	200	34– 9	53	20– 0	27	38–14	48	27–11	32	15–13	17	16–14	17	6– 3	6	0	....
1913	97–15	114	16– 5	25	14– 3	18	11–12	14	24– 7	27	14–15	15	10–10	10	5–11	5	0	....
1914	55–10	78	34– 4	52	7–13	10	9– 6	11	3– 7	4	0–12	1	0– 0	0	0– 0	0	5.33	....
1915	83–10	88	13– 3	18	6– 2	7	13–12	15	22– 2	22	15–11	15	10– 4	9	2– 8	2	7.00	....
Average	93.6	110	23.2	35	9.8	13	17.4	21	16.3	18	9.5	10	7.2	7	10.2	7	3.08	....
Standard grade—																		
1910	62–13	90	27–11	44	5–15	9	21– 7	27	6–13	9	0–15	1	0– 0	0	0– 0	0	....	....
1911	42– 6	40	4–15	7	3– 8	4	7– 1	7	8– 7	8	5–14	5	3–12	3	8–13	6	....	....
1912	65–12	82	12– 5	20	7– 5	10	17–15	22	9–10	11	8–25	10	7– 0	7	2– 0	2	3.00	....
1913	51–14	63	14–13	23	5– 8	7	8– 8	10	8– 6	9	7–14	8	4– 6	4	2– 7	2	4.00	....
1914	51–14	84	42–10	72	5– 4	7	4– 0	5	0– 0	0	0– 0	0	0– 0	0	0– 0	0	3.00	....
1915	32–14	36	5–14	8	3– 5	4	6– 4	7	8–12	9	2– 0	2	5– 8	5	1– 3	1	3.33	....
Average	51.3	66	18.1	29	5.2	7	10.9	13	7.0	8	4.3	4	3.4	3	2.4	2	3.33	....
Cull fruits—																		
1912	7– 9	13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	12–11	51	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	16–10	37	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.67	....
1915	2– 7	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.33	....
Average	9.8	26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.50	....
Total crop—																		
1910	158– 9	220	68–10	106	16–13	24	43– 9	55	20– 7	25	6– 1	7	3– 1	3	0– 0	0	....	....
1911	110–12	90	4–15	7	3– 8	4	15–13	16	14–11	14	10– 7	9	6– 1	5	55– 5	35	....	....
1912	233– 5	295	46–14	73	27– 5	37	56–13	70	37– 5	43	25– 6	27	23–14	24	8– 3	8	2.00	0
1913	162– 8	228	31– 2	48	19–11	25	20– 4	24	32–13	36	22–13	23	15– 0	14	8– 2	7	2.00	1
1914	124– 2	199	76–14	124	13– 1	17	13– 6	16	3– 7	4	0–12	1	0– 0	0	0– 0	0	4.33	1
1915	118–15	128	19– 1	26	9– 7	11	20– 0	22	30–14	31	17–11	17	15–12	14	3–11	3	5.56	2
Average	**151.4**	**193**	**41.3**	**64**	**15.0**	**20**	**28.3**	**34**	**23.3**	**26**	**13.9**	**14**	**10.6**	**10**	**12.6**	**9**	**3.47**	**1.00**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
32. Tree No. 23-63-20, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	96– 9	126	31– 0	49	12–12	17	12– 7	16	11–12	14	10–11	12	9– 8	10	8– 7	8	....	....
1911	193– 4	182	5– 0	7	9–11	12	19– 1	21	22–15	24	19– 9	20	30–13	28	86– 3	70	....	....
1912	102–15	109	7– 9	11	6– 2	8	12–14	15	16– 8	18	22– 6	23	14– 8	14	23– 0	20	0	....
1913	65– 0	82	15–14	25	13–10	18	14– 8	17	13–14	15	5– 0	5	2– 2	2	0– 0	0	0	....
1914	37– 3	52	19–14	31	7–12	10	3– 5	4	6– 4	7	0– 0	0	0– 0	0	0– 0	0	5.67	....
1915	115– 8	147	48–13	72	24– 7	30	18–10	21	17– 2	18	5– 5	5	1– 3	1	0– 0	0	3.00	....
Average	101.7	116	21.3	32	12.4	16	13.5	16	14.7	16	10.5	11	9.7	9	19.6	16	2.17	....
Standard grade—																		
1910	51– 7	78	21–12	38	5–15	9	10– 8	14	7–12	10	3– 8	5	2– 0	2	0– 0	0	....	....
1911	24– 2	30	3– 8	8	5– 0	6	3– 5	4	3– 9	4	0– 0	0	5– 4	5	3– 8	3	....	....
1912	50–15	55	7–12	11	3– 1	4	12–10	14	4– 9	5	4–14	5	3– 3	3	14–14	13	2.00	....
1913	21– 3	34	9– 2	20	3–15	5	3– 6	4	3–12	4	1– 0	1	0– 0	0	0– 0	0	1.50	....
1914	20– 3	30	16– 0	25	1–10	2	0–11	1	0–14	1	1– 0	1	0– 0	0	0– 0	0	4.00	....
1915	62–13	82	30–11	47	9–15	12	6– 2	7	9–10	10	5– 4	5	1– 3	1	0– 0	0	4.50	....
Average	38.4	52	14.8	25	4.9	6	6.1	7	5.1	6	2.6	3	1.9	2	3.1	3	2.00	....
Cull fruits—																		
1912	0– 6	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	7– 9	30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	6–14	15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.33	....
1915	5–10	11	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.00	....
Average	5.1	14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.17	....

Total crop—																		
1919	148–0	204	52–12	87	18–11	26	22–15	30	19–8	24	14–3	17	11–8	12	8–7	8	....	....
1911	217–6	212	8–8	15	14–11	18	22–6	25	26–8	28	19–9	20	36–1	33	89–11	73	....	....
1912	154–4	165	15–5	22	9–3	12	25–8	29	21–1	23	27–4	28	17–11	17	37–14	33	1.25	0
1913	93–12	146	25–0	45	17–9	23	17–14	21	17–10	19	6–0	6	2–2	2	0–0	0	.75	0
1914	64–4	97	35–14	56	9–6	12	4–0	5	7–2	8	1–0	1	0–0	0	0–0	0	5.00	2
1915	183–15	240	79–8	119	34–6	42	24–12	28	26–12	28	10–9	10	2–6	2	0–0	0	4.29	3
Average	**143.6**	**177**	**36.2**	**57**	**17.3**	**22**	**19.6**	**23**	**19.8**	**22**	**13.1**	**14**	**11.6**	**11**	**22.7**	**19**	**2.82**	**1.25**
33. Tree No. 23–60–18, Marsh strain:																		
Ivory-White grade—																		
1910	71–0	84	16–3	25	5–11	7	6–4	8	11–5	13	8–8	9	8–12	9	14–5	13	....	....
1911	178–3	178	11–2	15	8–9	10	24–2	27	28–9	31	20–7	20	40–3	37	45–3	38	....	....
1912	54–7	55	3–15	6	1–8	2	3–4	4	5–3	6	6–12	7	7–4	7	26–9	23	.67	....
1913	85–2	108	22–15	36	15–8	20	18–12	22	19–13	22	8–2	8	0–0	0	0–0	0	.50	....
1914	51–10	72	26–11	42	9–14	13	9–4	11	2–14	3	1–15	2	1–0	1	0–0	0	4.00	....
1915	88–10	100	21–3	29	12–11	15	22–11	25	14–10	15	10–9	10	5–10	5	1–4	1	6.00	....
Average	88.2	100	17.0	26	9.0	11	14.0	16	13.7	15	9.4	9	10.5	10	14.6	12	2.79	....
Standard grade—																		
1910	29–11	40	8–15	15	0–12	1	4–4	6	6–14	9	3–12	4	1–14	2	3–4	3	....	....
1911	25–7	28	4–10	8	1–13	2	0–13	1	4–14	5	5–1	5	4–11	4	3–9	3	....	....
1912	102–0	91	3–2	5	0–14	1	2–4	3	5–1	6	9–12	10	10–7	10	70–8	56	1.00	....
1913	49–7	71	20–3	37	9–8	12	10–6	12	4–8	5	4–14	5	0–0	0	0–0	0	1.00	....
1914	41–11	62	32–9	51	2–6	3	4–14	6	1–14	2	0–0	0	0–0	0	0–0	0	4.33	....
1915	49–10	56	13–3	18	5–15	7	10–14	12	13–15	14	3–4	3	1–3	1	1–4	1	6.00	....
Average	49.6	58	13.8	22	3.5	5	5.6	7	6.2	7	4.4	5	3.0	3	13.1	11	3.08	....
Cull fruits—																		
1912	5–8	6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	11–3	38	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	4–0	13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.33	....
1915	3–5	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.33	....
Average	6.0	15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.83	....
Total crop—																		
1910	100–11	124	25–2	40	6–7	8	10–8	14	18–3	22	12–4	13	10–10	11	17–9	16	....	....
1911	203–10	206	15–12	23	10–6	12	24–15	28	33–7	36	25–8	25	44–14	41	48–12	41	....	....
1912	161–15	152	7–1	11	2–6	3	5–8	7	10–4	12	16–8	17	17–11	17	97–1	79	.89	0
1913	145–12	217	43–2	73	25–0	32	29–2	34	24–5	27	13–0	13	0–0	0	0–0	0	.75	0
1914	97–5	147	59–4	93	12–4	16	14–2	17	4–12	5	1–15	2	1–0	1	0–0	0	3.89	2
1915	141–9	160	34–6	47	18–10	22	33–9	37	28–9	29	13–13	13	6–13	6	2–8	2	5.44	3
Average	**141.8**	**168**	**30.8**	**48**	**12.5**	**16**	**19.6**	**23**	**19.9**	**22**	**13.8**	**14**	**13.5**	**13**	**27.6**	**23**	**2.74**	**1.25**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
34. Tree No. 23-61-16, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	123–11	161	33– 9	52	19– 7	26	25–12	33	18– 8	22	18– 6	20	4–13	5	3– 4	3	....	....
1911	159– 2	127	1–15	3	0–13	1	7–10	8	9–11	10	4– 3	4	24– 7	21	110– 7	80	....	....
1912	138– 0	165	19–12	32	14–15	20	29– 4	37	16– 1	19	22– 4	24	13–15	14	21–13	19	3.00	....
1913	66– 2	72	9– 3	14	6– 4	8	2– 7	3	9– 7	10	17–11	18	6– 4	6	14–14	13	1.67	....
1914	20– 4	30	13–12	22	3– 2	4	0–12	1	2–10	3	0– 0	0	0– 0	0	0– 0	0	4.67	....
1915	71– 4	78	14–15	20	6– 8	8	7–13	9	17– 6	18	14– 9	14	7–10	7	2– 7	2	6.33	....
Average	96.4	106	15.5	24	8.5	11	12.3	15	12.3	14	12.8	13	9.5	9	25.5	20	3.92	....
Standard grade—																		
1910	53– 0	75	14–13	25	8–13	13	9–12	13	9–11	12	8–13	10	1–12	2	0– 0	0	....	....
1911	39–11	36	2– 9	5	3– 4	4	0– 0	0	5– 8	5	1– 1	1	4–10	4	22–11	17	....	....
1912	55– 1	68	9–15	17	7– 5	10	6– 4	8	15– 2	17	5– 7	6	5– 3	5	5–13	5	2.33	....
1913	38– 4	49	11– 0	20	7–11	10	3–10	4	1–14	2	5– 3	5	4– 5	4	4– 9	4	3.00	....
1914	31– 1	49	18– 1	33	6– 4	8	4– 2	5	2–10	3	0– 0	0	0– 0	0	0– 0	0	4.33	....
1915	36– 3	40	5– 0	8	3– 5	4	9–12	11	4–13	5	6– 6	6	4– 9	4	2– 6	2	5.67	....
Average	42.2	53	10.3	18	6.1	8	3.5	7	6.6	7	4.4	5	3.4	3	5.9	4	3.83	....
Cull fruits—																		
1912	1– 6	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	6–13	29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	7– 0	20	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.33	....
1915	2– 0	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.00	....
Average	4.3	14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.17	....

Total crop—																		
1910	176–11	236	48– 6	77	28– 4	39	35– 8	46	28– 3	34	26– 9	30	6– 9	7	3– 4	3	....	....
1911	198–13	163	4– 8	8	4– 1	5	7–10	8	15– 3	15	5– 4	5	29– 1	25	133– 2	97	....	....
1912	194– 7	236	29–11	49	22– 4	30	35– 8	45	31– 3	36	27–11	30	19– 2	19	27–10	24	2.56	12
1913	111– 3	150	20– 3	34	13–15	18	6– 1	7	11– 5	12	22–14	23	10– 9	10	19– 7	17	2.33	0
1914	58– 5	99	31–13	55	9– 6	12	4–14	6	5– 4	6	0– 0	0	0– 0	0	0– 0	0	4.44	2
1915	109– 7	121	19–15	28	9–13	12	17– 9	20	22– 3	23	20–15	20	12– 3	11	4–13	4	5.43	4
Average	**141.5**	**168**	**25.8**	**42**	**14.6**	**19**	**17.8**	**22**	**18.9**	**21**	**17.2**	**18**	**12.9**	**12**	**31.4**	**24**	**3.69**	**4.50**
35. Tree No. 23-60-13, Marsh strain:																		
Ivory-White grade—																		
1910	109–15	108	3– 9	5	3–13	5	10–15	13	10–10	12	15– 5	16	17– 4	17	48– 7	40	....	....
1911	185– 7	193	9–14	16	17–13	22	24– 0	27	38–13	41	31– 7	31	25– 9	24	37–15	32	....	....
1912	111–13	125	13– 8	22	9– 0	12	14–11	18	13– 5	15	13– 2	14	17– 3	17	31– 0	27	0	....
1913	71– 8	82	9– 6	14	10– 2	13	14– 7	17	16– 9	18	9–13	10	5– 5	5	5–14	5	0	....
1914	29– 3	44	20– 8	33	7– 0	9	0–13	1	0–14	1	0– 0	0	0– 0	0	0– 0	0	6.00	....
1915	29– 0	26	0–13	1	1–13	2	3–12	4	3– 0	3	5– 7	5	4–10	4	9– 9	7	4.33	....
Average	89.5	96	9.6	15	8.3	11	11.4	13	14.0	15	12.5	13	11.7	11	22.1	19	2.58	....
Standard grade—																		
1910	30–11	36	2– 0	3	1– 8	2	4– 2	6	3– 9	5	4–12	5	4– 2	5	10–10	10	....	....
1911	62–15	69	12– 2	19	3– 8	4	9– 5	10	10–10	11	7– 4	7	8– 5	8	11–13	10	....	....
1912	83– 7	93	10– 5	16	3– 1	4	7–14	10	14– 7	17	16– 6	17	11– 0	11	20– 6	18	.67	....
1913	36–15	44	7– 8	12	7–12	10	4– 5	5	9– 6	10	1– 0	1	2– 2	2	4–14	4	6.00	....
1914	47–12	72	35– 4	57	5– 8	7	3– 6	4	2– 0	3	1– 0	1	0– 0	0	0– 0	0	7.00	....
1915	16– 9	16	0–11	1	2–10	3	3–13	4	2– 0	2	1– 3	1	1– 3	1	5– 1	4	5.00	....
Average	46.4	55	11.3	18	4. 0	5	5.5	7	7.0	8	5.2	5	4.4	5	8.8	7	4.67	....
Cull fruits—																		
1912	2–10	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	7–13	33	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	13– 8	31	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.00	....
1915	1– 4	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.00	....
Average	6.3	18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.50	....
Total crop—																		
1910	140–10	144	5– 9	8	5– 5	7	15– 1	19	14– 3	17	20– 1	21	21– 6	22	59– 1	50	....	....
1911	248– 6	262	22– 0	35	21– 5	26	33– 5	37	49– 7	52	38–11	38	33–14	32	49–12	42	....	....
1912	197–14	222	23–13	38	12– 1	16	22– 9	28	27–12	32	29– 8	31	28– 3	28	51– 6	45	.44	2
1913	116– 4	159	16–14	26	17–14	23	18–12	22	25–15	28	10–13	11	7– 7	7	10–12	9	3.00	0
1914	90– 7	147	55–12	90	12– 8	16	4– 3	5	3– 8	4	1– 0	1	0– 0	0	0– 0	0	6.00	1
1915	46–13	44	1– 8	2	4– 7	5	7– 9	8	5– 0	5	6–10	6	5–13	5	14–10	11	4.57	0
Average	**140.1**	**163**	**20.9**	**33**	**12.3**	**16**	**16.9**	**20**	**21.0**	**23**	**17.8**	**18**	**16.1**	**16**	**30.9**	**26**	**3.50**	**0.75**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
36. Tree No. 23-63-18, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	118- 3	161	50-13	79	16- 5	22	23- 9	29	12- 8	15	13- 0	14	2- 0	2	0- 0	0	......	......
1911	211-15	190	4- 6	7	5- 1	6	8-13	10	26- 0	27	22- 9	22	28- 8	26	116-10	92	......	......
1912	126- 2	125	5- 6	8	6- 6	8	14-12	17	16-10	18	17-10	18	17- 1	16	48- 5	40	0	......
1913	79- 2	86	7-10	12	9- 9	12	6- 9	8	19- 6	21	10-12	11	14- 0	13	11- 4	9	2.00	......
1914	41-12	54	18- 8	27	9- 9	12	7- 0	8	4-11	5	2- 0	2	0- 0	0	0- 0	0	5.67	......
1915	40- 2	37	0-12	1	5- 2	6	3-12	4	5- 0	5	5- 6	5	5-12	5	14- 6	11	3.00	......
Average	102.9	109	14.6	22	8.7	11	10.7	13	14.0	15	11.9	12	11.2	10	31.8	25	2.67	......
Standard grade—																		
1910	61- 0	95	33- 4	57	8- 7	13	11- 6	16	5- 4	6	2-11	3	0- 0	0	0- 0	0	......	......
1911	40- 1	40	3-15	7	1- 9	2	2-12	3	3-12	4	2-14	3	5- 6	5	19-13	16	......	......
1912	32- 0	34	3- 6	5	2- 6	3	3- 8	4	5-10	6	4-13	5	2- 2	2	10- 3	9	2.67	......
1913	17-10	25	4- 1	11	1-10	2	2-10	3	1-14	2	2-15	3	2- 3	2	2- 5	2	4.67	......
1914	26- 8	36	11- 6	18	9-14	12	2- 7	3	2-13	3	0- 0	0	0- 0	0	0- 0	0	5.33	......
1915	22- 7	21	0- 0	0	0-14	1	1- 0	1	8- 0	8	4- 4	4	3- 9	3	4-12	4	4.50	......
Average	33.3	42	9.3	16	4.1	6	4.0	5	4.6	5	2.9	3	2.2	2	6.1	6	4.29	......
Cull fruits—																		
1912	5-14	7	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1913	3-14	6	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1914	8- 2	18	......	......	......	......	......	......	......	......	......	......	......	......	......	......	6.33	......
1915	0-14	2	......	......	......	......	......	......	......	......	......	......	......	......	......	......	3.00	......
Average	4.7	8	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.67	......

Total crop—																		
1910	179- 3	256	84- 1	136	24-12	35	34-15	45	17-12	21	15-11	17	2- 0	2	0- 0	0	....	....
1911	252- 0	230	8- 5	14	6-10	8	11- 9	13	29-12	31	25- 7	25	33-14	31	136- 7	108	....	....
1912	164- 0	159	8-12	13	8-12	11	18- 4	21	22- 4	24	22- 7	23	19- 3	18	58- 8	49	1.78	0
1913	100-10	117	11-11	23	11- 3	14	9- 3	11	21- 4	23	13-11	14	16- 3	15	13- 9	11	3.33	0
1914	76- 6	108	29-14	45	19- 7	24	9- 7	11	7- 8	8	2- 0	2	0- 0	0	0- 0	0	5.78	0
1915	63- 7	60	0-12	1	6- 0	7	4-12	5	13- 0	13	9-10	9	9- 5	8	19- 2	15	3.43	3
Average	**139.3**	**156**	**23.9**	**39**	**12.8**	**17**	**14.7**	**18**	**18.6**	**20**	**14.8**	**15**	**13.4**	**12**	**37.9**	**31**	**2.39**	**0.75**
37. **Tree No. 23-60-17,** Marsh strain:																		
Ivory-White grade—																		
1910	44-14	53	5- 2	8	3- 9	5	7- 3	9	8- 6	10	10- 4	11	2- 9	3	7-13	7	....	....
1911	139-10	134	7- 4	10	4- 3	5	19- 7	21	17-10	20	14-10	14	30- 0	27	46- 8	37	....	....
1912	122- 8	139	14- 0	21	9-13	13	23- 7	28	25-15	29	19- 8	20	16- 9	16	18- 4	12	0	....
1913	109- 4	129	18-10	28	17- 4	22	22- 1	26	26-12	29	10- 9	11	8- 4	8	5-12	5	3.67	....
1914	80- 6	113	43-14	68	22- 8	29	8- 8	10	4- 8	5	1- 0	1	0- 0	0	0- 0	0	3.00	....
1915	39- 1	37	3- 1	4	2- 9	3	3-12	4	5-15	6	7- 6	7	5-10	5	10-12	8	4.33	....
Average	89.3	101	15.3	23	10.0	13	14.0	16	14.8	17	10.6	11	10.5	10	14.0	12	2.75	....
Standard grade—																		
1910	31-0	37	2-10	4	3- 1	4	5- 3	7	3-9	5	6-15	8	3-15	4	5-11	5	....	....
1911	32-0	35	6- 4	10	2- 8	3	6- 4	7	0-13	1	2- 0	2	5- 4	5	8-15	7	....	....
1912	76-7	81	5- 3	8	6- 8	9	9- 1	11	7-15	9	9- 5	10	10- 6	10	28- 1	24	1.50	....
1913	53-3	66	13- 1	21	12-10	16	8-11	10	11- 4	12	4- 2	4	1- 0	1	2- 7	2	4.67	....
1914	47-9	69	25- 8	41	12- 5	16	4- 2	6	5-10	6	0- 0	0	0- 0	0	0- 0	0	4.67	....
1915	22-2	23	3- 2	5	0-14	1	3-12	4	4-15	5	3- 5	3	1- 2	1	5- 0	4	2.33	....
Average	43.7	52	9.3	15	6.3	8	6.2	8	5.7	6	4.2	4	3.6	3	8.4	7	3.29	....
Cull fruits—																		
1912	2-4	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	10-14	41	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	20-11	18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.00	....
1915	1-8	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.50	....
Average	8.8	16	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.25	....
Total crop—																		
1910	75-14	90	7-12	12	6-10	9	12- 6	16	11-15	15	17- 3	19	6- 8	7	13- 8	12	....	....
1911	171-10	169	13- 8	20	6-11	8	25-11	28	18- 7	21	16-10	16	35- 4	32	55- 7	44	....	....
1912	201- 3	224	19- 3	29	16- 5	22	32- 8	39	33-14	38	28-13	30	26-15	26	41- 5	36	1.00	0
1913	173- 5	236	31-11	49	29-14	38	30-12	36	38- 0	41	14-11	15	9- 4	9	8- 3	7	4.17	1
1914	148-10	200	69- 6	109	34-13	45	12-10	16	10- 2	11	1- 0	1	0- 0	0	0- 0	0	3.22	1
1915	62-11	62	6- 3	9	3- 7	4	7- 8	8	10-14	11	10-11	10	6-12	6	15-12	12	3.63	1
Average	**138.9**	**164**	**24.6**	**38**	**16.3**	**21**	**20.2**	**24**	**20.5**	**23**	**14.8**	**15**	**14.1**	**13**	**22.4**	**19**	**3.00**	**0.75**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
38. Tree No. 23-62-20, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	81-12	81	3- 4	5	2- 7	4	8- 5	10	5-15	7	7- 5	8	8-12	9	45-12	38	....	....
1911	102- 0	102	10- 4	15	10- 6	12	8- 1	9	17- 0	18	9- 4	9	14- 1	13	33- 0	26	....	....
1912	99-14	111	11-12	19	4- 7	6	9-12	12	15- 1	17	12- 1	13	20- 2	20	26-11	24	1.33	....
1913	78-12	97	16-14	26	17- 0	22	11- 0	13	16-13	19	9-12	10	5- 2	5	2- 3	2	.33	....
1914	50- 0	74	30- 8	49	9-12	14	4- 2	5	4-10	5	1- 0	1	0- 0	0	0- 0	0	5.67	....
1915	45-11	49	7-12	12	4- 2	5	6- 8	7	10- 2	10	8- 4	8	2- 5	2	6-10	5	6.00	....
Average	76.3	86	13.4	21	8.0	11	7.9	9	11.6	13	7.9	8	8.4	8	19.0	16	3.33	....
Standard grade—																		
1910	45-14	51	4- 8	7	3- 0	4	5- 2	7	2-13	3	9-14	11	6- 2	6	14- 7	13	....	....
1911	59- 0	70	15- 1	24	14- 9	17	7- 4	8	7-13	8	4- 0	4	5- 6	5	4-15	4	....	....
1912	74-10	81	3- 6	6	3-13	5	8-15	11	13- 2	15	15- 4	16	4- 2	4	26- 0	24	.50	....
1913	52- 1	70	22-14	36	9- 4	12	5-15	7	8-14	10	3- 0	3	1- 0	1	1- 2	1	4.33	....
1914	68- 6	101	38-11	65	14- 8	19	7-10	9	6- 9	7	1- 0	1	0- 0	0	0- 0	0	2.67	....
1915	43- 1	50	14-10	21	4-15	6	6- 5	7	7- 1	7	5- 5	5	2- 3	2	2-10	2	5.67	....
Average	57.2	70	16.5	27	8.4	10	6.9	8	7.7	8	6.4	7	3.1	3	8.2	7	3.29	....
Cull fruits—																		
1912	6-12	9	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	6- 9	26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	16- 0	36	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.67	....
1915	0-14	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.00	....
Average	7.5	18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.84	....

Total crop—																		
1910	127-10	132	7-12	12	5- 7	8	13- 7	17	8-12	10	17- 3	19	14-14	15	60- 3	51	....	....
1911	161- 0	172	25- 5	39	24-15	29	15- 5	17	24-13	26	13- 4	13	19- 7	18	37-15	30	....	....
1912	181- 4	201	15- 2	25	8- 4	11	18-11	23	28- 3	32	27- 5	29	24- 4	24	52-11	48	.78	0
1913	137- 6	193	39-12	62	26- 4	34	16-15	20	25-11	29	12-12	13	6- 2	6	3- 5	3	2.33	1
1914	134- 6	211	69- 3	114	24- 4	33	11-12	14	11- 3	12	2- 0	2	0- 0	0	0- 0	0	4.67	1
1915	89-10	100	22- 6	33	9- 1	11	12-13	14	17- 3	17	13- 9	13	4- 8	4	9- 4	7	5.86	4
Average	**138.5**	**168**	**29.9**	**48**	**16.4**	**21**	**14.8**	**18**	**19.3**	**21**	**14.3**	**15**	**11.5**	**11**	**27.2**	**23**	**3.41**	**1.50**
39. Tree No. 23-62-12, Marsh strain: Ivory-White grade—																		
1910	130- 6	152	24- 5	38	13- 0	17	19- 9	24	17-15	20	17- 2	18	17- 2	17	21-5	18	....	....
1911	142- 8	169	23- 8	34	21- 2	27	27- 2	34	26- 4	29	24-10	26	12- 0	12	7-14	7	....	....
1912	108- 0	119	6- 9	11	6- 0	8	22- 5	28	16-11	19	16- 5	17	9- 8	9	30-10	27	.33	....
1913	72-11	87	7-12	14	8- 4	11	15-11	19	13- 0	15	11- 5	12	11- 0	11	5-11	5	1.33	....
1914	52-13	76	36- 2	56	7- 0	9	5- 0	6	4-11	5	0- 0	0	0- 0	0	0- 0	0	4.00	....
1915	29- 6	28	1- 7	2	1-11	2	3- 9	4	5- 1	5	5- 6	5	7- 4	6	5- 0	4	6.67	....
Average	89.3	105	16.6	26	9.5	12	15.5	19	13.9	16	12.5	13	9.5	9	11.8	10	3.08	....
Standard grade—																		
1910	60- 1	80	17-11	30	10- 7	14	11- 5	14	7-11	9	5- 6	6	4- 0	4	3- 9	3	....	....
1911	58- 8	74	16-12	25	7-14	10	16-11	20	9-11	11	0-12	1	5-12	6	1- 0	1	....	....
1912	44- 0	51	7- 9	12	5- 4	7	5-13	7	6- 5	7	5-13	6	6- 2	6	7- 2	6	1.00	....
1913	24-10	35	6- 4	14	5- 6	7	2- 8	3	7- 3	8	1- 0	1	1- 2	1	1- 3	1	1.33	....
1914	46- 8	73	34-12	58	8- 6	11	2- 8	3	0-14	1	0- 0	0	0- 0	0	0- 0	0	5.33	....
1915	11- 7	11	0-12	1	0- 0	0	1-14	2	3- 0	3	3- 5	3	1- 4	1	1- 4	1	4.67	....
Average	40.9	54	14.0	23	6.2	8	6.8	8	5.8	6	2.7	3	3.0	3	2.3	2	3.08	....
Cull fruits—																		
1912	9- 5	13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	4- 8	13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	15-12	32	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.33	....
1915	2-15	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.00	....
Average	8.1	16	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.17	....
Total crop—																		
1910	190- 7	232	42- 0	68	23- 7	31	30-14	38	25-10	29	22- 8	24	21- 2	21	24-14	21	....	....
1911	201- 0	243	40- 4	59	29- 0	37	43-13	54	35-15	40	25- 6	27	17-12	18	8-14	8	....	....
1912	161- 5	184	14- 2	23	11- 4	15	28- 2	35	23- 0	26	22- 2	23	15-10	15	37-12	33	.78	0
1913	101-13	135	14- 0	28	13-10	18	18- 3	22	20- 3	23	12- 5	13	12- 2	12	6-14	6	1.33	1
1914	115- 1	181	70-14	114	15- 6	20	7- 8	9	5- 9	6	0- 0	0	0- 0	0	0- 0	0	4.89	1
1915	43-12	44	2- 3	3	1-11	2	5- 7	6	8- 1	8	8-11	8	8- 8	7	6- 4	5	5.89	2
Average	**135.6**	**170**	**30.6**	**49**	**15.7**	**21**	**22.3**	**27**	**19.7**	**22**	**15.2**	**16**	**12.5**	**12**	**14.1**	**12**	**3.22**	**1.00**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
40. Tree No. 23-59-12, Alternate-Bearing strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	101- 2	137	30- 6	49	17- 7	24	19- 9	25	16-12	20	9-12	11	5- 2	6	2- 2	2	....	....
1911	48-14	35	0- 5	1	0- 9	1	0- 0	0	0-12	1	1-15	2	5- 8	5	39-13	25	....	....
1912	163-12	234	74-13	123	23- 1	32	28- 5	36	23- 9	28	10-14	12	2- 0	2	1- 2	1	1.67	....
1913	103- 5	106	4- 3	6	6- 6	8	11-11	14	19- 5	21	17- 8	18	16- 9	16	27-11	23	.33	....
1914	59-11	77	17- 2	25	20-12	27	8- 7	10	9- 0	10	2- 8	3	1-14	2	0- 0	0	5.33	....
1915	33- 3	33	5- 4	7	1-11	2	4-12	5	7- 1	7	4- 5	4	1- 2	1	9- 0	7	4.00	....
Average	85.0	104	22.0	35	11.6	16	12.1	15	12.7	15	7.8	8	5.4	5	13.2	10	2.83	....
Standard grade—																		
1910	61- 1	92	20- 9	36	10-10	16	15- 5	21	10- 2	13	4- 7	6	0- 0	0	0- 0	0	....	....
1911	17- 8	15	0- 3	1	0- 0	0	0- 0	0	0- 0	0	1-10	2	3- 6	3	12- 5	9	....	....
1912	80-13	112	33-12	56	7-10	10	16-10	21	14-12	17	2-13	3	2-15	3	2- 5	2	4.17	....
1913	49-14	57	9- 9	14	6- 8	8	7- 7	9	6-10	7	9-11	10	2- 0	2	8- 1	7	1.33	....
1914	41-11	58	20- 8	33	6-13	9	3- 4	4	11- 2	12	0- 0	0	0- 0	0	0- 0	0	3.33	....
1915	17- 0	17	2- 1	3	0-13	1	0-13	1	2- 1	2	6- 9	6	2- 5	2	2- 6	2	5.33	....
Average	44.7	59	14.4	24	5. 4	7	7.2	9	7.5	8	4.2	5	1.7	2	4.3	3	3.54	....
Cull fruits—																		
1912	5- 3	11	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	11- 7	30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	15- 0	29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1915	0-13	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.00	....
Average	8.1	18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.00	....

Total crop—																		
1910	162- 3	229	50-15	85	28- 1	40	34-14	46	26-14	33	14- 3	17	5- 2	6	2- 2	2	....	....
1911	66- 6	50	0- 8	2	0- 9	1	0- 0	0	0-12	1	3- 9	4	8-14	8	52- 2	34	....	....
1912	249-12	357	108- 9	179	30-11	42	44-15	57	38- 5	45	13-11	15	4-15	5	3- 7	3	3.33	7
1913	164-10	193	13-12	20	12-14	16	19- 2	23	25-15	28	27- 3	28	18- 9	18	35-12	30	.83	0
1914	116- 6	164	37-10	58	27- 9	36	11-11	14	20- 2	22	2- 8	3	1-14	2	0- 0	0	4.22	0
1915	51- 0	51	7- 5	10	2- 8	3	5- 9	6	9- 2	9	10-14	10	3- 7	3	11- 6	9	4.14	0
Average	**135.1**	**174**	**36.4**	**59**	**17.0**	**23**	**19.3**	**24**	**20.2**	**23**	**12.0**	**13**	**7.1**	**7**	**17.5**	**13**	**3.13**	**1.75**
41. **Tree No. 23-61-12,** Marsh strain:																		
Ivory-White grade—																		
1910	119- 7	149	30-13	46	18- 2	24	23- 8	29	17-13	20	11- 2	12	9-11	10	8- 6	8	....	....
1911	122- 8	114	3-14	6	5-13	7	8-14	10	8-14	9	19- 3	19	20- 6	19	55- 8	44	....	....
1912	142- 1	160	14- 2	22	10- 9	14	22- 3	27	28-10	32	24- 2	26	14- 1	14	28- 6	25	2.67	....
1913	61- 8	66	4- 1	6	6-12	9	7-11	9	10-15	12	11- 2	11	12-10	12	8- 5	7	0	....
1914	49-10	70	28-14	45	9- 8	12	7-12	9	3- 8	4	0- 0	0	0- 0	0	0- 0	0	6.67	....
1915	42-10	41	2- 4	3	1-12	2	6- 6	7	7-13	8	7-10	7	9- 4	8	7- 9	6	4.33	....
Average	89.7	100	14.0	21	8.8	12	12.7	15	12.9	14	12.2	12	11.0	10	18.0	15	3.42	....
Standard grade—																		
1910	50-11	69	16- 0	25	8- 7	12	10- 1	13	9-13	12	5- 5	6	0- 0	0	1- 1	1	....	....
1911	64-12	65	5-13	9	7-10	9	6- 2	7	6- 8	7	1-14	2	14- 3	13	22-10	18	....	....
1912	52-11	62	10- 3	16	6- 1	8	9- 0	11	8- 5	9	6- 0	6	6- 6	6	6-12	6	3.33	....
1913	28-12	34	9- 4	13	3- 3	4	5- 4	6	3-12	4	3-15	4	2- 1	2	1- 5	1	5.33	....
1914	39-14	66	31-14	56	3- 1	4	4- 2	5	0-13	1	0- 0	0	0- 0	0	0- 0	0	6.67	....
1915	22-11	24	5- 0	7	0-13	1	1-14	2	3-12	4	5- 7	5	2- 4	2	3- 9	3	3.00	....
Average	43.2	53	13.0	21	4.8	6	6.1	7	5.5	6	3.8	4	4.1	4	5.9	5	4.58	....
Cull fruits—																		
1912	1- 3	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	3- 2	19	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	7- 4	17	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.67	....
1915	0- 9	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.00	....
Average	3.0	10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.33	....
Total crop—																		
1910	170- 2	218	46-13	71	26- 9	36	33- 9	42	27-10	32	16- 7	18	9-11	10	9- 7	9	....	....
1911	187- 4	179	9-11	15	13- 7	16	15- 0	17	15- 6	16	21- 1	21	34- 9	32	78- 2	62	....	....
1912	195-15	225	24- 5	38	16-10	22	31- 3	38	36-15	41	30- 2	32	20- 7	20	35- 2	31	3.11	1
1913	93- 6	119	13- 5	19	9-15	13	12-15	15	14-11	16	15- 1	15	14-11	14	9-10	8	2.67	1
1914	96-12	153	60-12	101	12- 9	16	11-14	14	4- 5	5	0- 0	0	0- 0	0	0- 0	0	5.33	0
1915	65-14	66	7- 4	10	2- 9	3	8- 4	9	11- 9	12	13- 1	12	11- 8	10	11- 2	9	4.00	1
Average	**134.9**	**160**	**27.0**	**42**	**13.6**	**18**	**18.8**	**23**	**18.4**	**20**	**16.0**	**16**	**15.1**	**14**	**23.9**	**20**	**3.78**	**0.75**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
42. Tree No. 23-62-18, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	61–10	71	6– 7	10	8– 9	11	7– 5	9	7–13	9	9– 6	10	11–12	12	10– 6	10	....	....
1911	177–12	147	5– 6	8	4–11	6	14– 5	16	15–11	17	19– 1	19	30– 1	28	88– 9	53	....	....
1912	101–14	97	3– 6	5	5– 7	7	5–12	7	7– 2	8	7–12	8	12– 5	12	60– 2	50	0.33	....
1913	88–14	103	11– 8	18	13– 5	17	9– 4	11	27–14	31	9–11	10	8– 0	8	9– 4	8	0	....
1914	44– 3	56	12– 8	19	10–12	14	10– 8	12	6– 7	7	4– 0	4	0– 0	0	0– 0	0	4.33	....
1915	75– 9	76	9–12	13	3– 6	4	11– 3	12	15– 1	15	15–15	15	10– 4	9	10– 0	8	6.00	....
Average	91.6	92	8.2	12	7.7	10	9.7	11	13.3	14	11.0	11	12.1	11	29.7	21	2.67	....
Standard grade—																		
1910	34– 7	43	6–12	11	6– 2	9	5–13	7	3–12	4	3–13	4	6– 1	6	2– 2	2	....	....
1911	33–14	39	8– 0	13	0–10	1	4– 4	5	2– 7	3	4– 1	4	6– 4	6	8– 4	7	....	....
1912	42–11	39	1– 2	2	0– 0	0	3– 4	4	2–11	3	0–15	1	3– 0	3	31–11	26	2.33	....
1913	33–10	47	14– 2	26	4– 0	5	4– 5	5	4–10	5	2– 0	2	2– 3	2	2– 6	2	1.33	....
1914	46– 9	60	17– 0	26	7– 4	9	6–12	8	11– 7	13	2– 0	2	2– 2	2	0– 0	0	2.67	....
1915	24– 2	24	2–14	4	1–11	2	2–12	3	5– 0	5	4–10	4	3– 4	3	3–15	3	4.00	....
Average	35.9	42	8.3	14	3.3	4	4.5	5	5.0	6	2.9	3	3.8	4	8.1	7	2.58	....
Cull fruits—																		
1912	0– 0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	13– 3	51	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	6– 8	18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.67	....
1915	1–10	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.33	....
Average	5.3	18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.00	....

Total crop—																		
1910	96– 1	114	13– 3	21	14–11	20	13– 2	16	11– 9	13	13– 3	14	17–13	18	12– 8	12	......	......
1911	211–10	186	13– 6	21	5–5	7	18– 9	21	18– 2	20	23– 2	23	36– 5	34	96–13	60	......	......
1912	144– 9	136	4– 8	7	5– 7	7	9– 0	11	9–13	11	8–11	9	15– 5	15	91–13	76	1.67	0
1913	135–11	201	25–10	44	17– 5	22	13– 9	16	32– 8	36	11–11	12	10– 3	10	11–10	10	.67	0
1914	97– 4	134	29– 8	45	18– 0	23	17– 4	20	17–14	20	6– 0	6	2– 2	2	0– 0	0	4.89	3
1915	101– 5	103	12–10	17	5– 1	6	13–15	15	20– 1	20	20– 9	19	13– 8	12	13–15	11	5.44	4
Average	**131.1**	**146**	**16.5**	**26**	**11.0**	**14**	**14.2**	**17**	**18.3**	**20**	**13.9**	**14**	**15.9**	**15**	**37.8**	**28**	**3.17**	**1.75**
43. Tree No. 23-59-6, Marsh strain:																		
Ivory-White grade—																		
1910	136– 3	158	13– 4	20	14– 2	19	32– 0	39	25– 4	29	19–12	21	17– 8	17	14– 5	13	......	......
1911	112–10	104	8– 6	12	0– 0	0	10– 9	12	5–13	6	15– 2	15	21– 0	19	51–12	40	......	......
1912	98– 7	100	2–12	4	4– 8	6	8– 5	10	12– 8	14	16–12	18	16– 5	16	37– 5	32	1.67	......
1913	60– 8	69	5–14	10	7–13	10	9–14	12	12–14	14	8–13	9	11–10	11	3–10	3	.67	......
1914	48–13	69	27– 8	43	10– 3	13	7–10	9	2–10	3	0–14	1	0– 0	0	0– 0	0	6.67	......
1915	31–15	30	1–11	2	2–10	3	1–12	2	3– 1	3	6– 5	6	9– 2	8	7– 6	6	4.00	......
Average	81.4	88	9.9	15	6.5	8	11.7	14	10.4	11	11.3	12	12.6	12	19.1	16	3.25	......
Standard grade—																		
1910	11–17	18	4–15	8	3– 8	5	3– 2	4	0– 8	1	0– 0	0	0– 0	0	0– 0	0	......	......
1911	64– 2	64	5– 1	7	2– 6	3	8– 5	9	3–14	4	9– 2	9	13– 2	12	22– 4	20	......	......
1912	50– 5	52	5– 6	9	2–15	4	4– 2	5	3–11	4	4–14	5	3–14	4	25– 7	21	1.67	......
1913	37– 2	46	7–14	15	5–12	7	7– 0	8	5–10	6	5– 4	5	4– 6	4	1– 4	1	2.67	......
1914	52– 9	80	34–14	58	9–12	13	6– 1	7	1–14	2	0– 0	0	0– 0	0	0– 0	0	5.00	......
1915	24–15	25	2– 3	3	2– 8	3	3– 9	4	5– 1	5	2– 3	2	5–10	5	3–13	3	4.00	......
Average	40.2	48	10.1	17	4.5	6	5.4	6	3.4	4	3.5	3	4.5	4	8.8	7	3.34	......
Cull fruits—																		
1912	9– 8	12	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1913	6– 1	25	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1914	13– 5	31	......	......	......	......	......	......	......	......	......	......	......	......	......	......	5.33	......
1915	1–12	2	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.00	......
Average	7.7	18	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.67	......
Total crop—																		
1910	148– 4	176	18– 3	28	17–10	24	35– 2	43	25–12	30	19–12	21	17– 8	17	14– 5	13	......	......
1911	176–12	168	13– 7	19	2– 6	3	18–14	21	9–11	10	24– 4	24	34– 2	31	74– 0	60	......	......
1912	158– 4	152	8– 2	13	7– 7	10	12– 7	15	16– 3	18	21–10	23	20– 3	20	62–12	53	1.67	0
1913	103–11	140	13–12	25	13– 9	17	16–14	20	18– 8	20	14– 1	14	16– 0	15	4–14	4	1.67	0
1914	114–11	180	62– 6	101	19–15	26	13–11	16	4– 8	5	0–14	1	0– 0	0	0– 0	0	5.67	2
1915	58–10	57	3–14	5	5– 2	6	5– 5	6	8– 2	8	8– 8	8	14–12	13	11– 3	9	4.00	0
Average	**126.7**	**148**	**20.0**	**32**	**11.0**	**14**	**17.1**	**20**	**13.8**	**15**	**14.8**	**15**	**17.1**	**16**	**27.9**	**23**	**3.25**	**0.50**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
44. **Tree No. 23-63-23**, Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	67- 8	83	33-12	22	8- 6	11	7- 0	9	11- 3	13	12- 2	13	6- 9	7	8- 8	8	......	......
1911	101- 6	83	1- 6	2	1-12	2	2-13	3	6- 0	6	8- 5	8	17- 4	15	63-14	47	......	......
1912	110- 0	138	21- 2	35	11-12	16	24- 8	31	13-12	18	12- 0	13	8-14	9	18- 0	16	1.00	......
1913	83-11	92	5-13	9	10- 2	13	12-10	15	17-10	19	18-14	19	11-10	11	7- 0	6	.67	......
1914	51-14	73	28-10	45	6-10	9	7- 8	9	7- 2	8	1- 0	1	1- 0	1	0- 0	0	4.67	......
1915	39-10	39	2- 4	3	2- 9	3	6- 6	7	9-15	10	5- 2	5	4- 8	4	8-14	7	5.67	......
Average	75.7	85	12.1	19	6.9	9	10.1	12	10.9	12	9.6	10	8.3	8	17.7	14	3.00	......
Standard grade—																		
1910	28-14	41	7-11	14	4- 8	7	4- 8	6	7- 4	9	2-14	3	2- 1	2	0- 0	0	......	......
1911	36- 1	34	3- 1	5	3- 6	4	2-12	3	2-15	3	1- 0	1	5-14	5	17- 1	13	......	......
1912	68- 8	87	14-15	25	10- 8	14	12-13	16	8- 7	10	8- 5	9	6-13	7	6-11	6	1.67	......
1913	45-11	57	15-12	25	7- 0	9	2- 8	3	6- 9	7	6-14	7	2- 4	2	4-12	4	2.00	......
1914	56- 1	89	43- 0	73	5- 6	7	6-11	8	1- 0	1	0- 0	0	0- 0	0	0- 0	0	4.33	......
1915	21- 7	22	3-11	5	1-12	2	2-14	3	7- 3	7	1- 1	1	2- 5	2	2- 9	2	4.67	......
Average	42.8	55	14.7	25	5.4	7	5.4	7	5.6	6	3.3	3	3.2	3	5.2	4	3.17	......
Cull fruits—																		
1912	8-15	15	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1913	6- 5	23	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1914	24-13	57	......	......	......	......	......	......	......	......	......	......	......	......	......	......	3.67	......
1915	0- 0	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Average	10.0	24	......	......	......	......	......	......	......	......	......	......	......	......	......	......	3.67	......

Total crop—																		
1910	96- 6	124	21- 7	36	12-14	18	11- 8	15	18- 7	22	15- 0	16	8-10	9	8- 8	8		
1911	137- 7	117	4- 7	7	5- 2	6	5- 9	6	8-15	9	9- 5	9	23- 2	20	80-15	60		
1912	187- 7	240	36- 1	60	22- 4	30	37- 5	47	22- 3	28	20- 5	22	15-11	16	24-11	22	1.44	1
1913	135-11	172	21- 9	34	17- 2	22	15- 2	18	24- 3	26	25-12	26	13-14	13	11-12	10	1.33	0
1914	132-12	219	71-10	118	12- 0	16	14- 3	17	8- 2	9	1- 0	1	1- 0	1	0- 0	0	4.22	1
1915	61- 1	61	5-15	8	4- 5	5	9- 4	10	17- 2	17	6- 3	6	6-13	6	11- 7	9	5.17	2
Average	**125.1**	**156**	**26.8**	**44**	**12.3**	**16**	**15.5**	**19**	**16.5**	**19**	**12.9**	**13**	**11.5**	**11**	**22.9**	**18**	**3.04**	**1.00**
45. **Tree No. 23-62-19**, Marsh strain:																		
Ivory-White grade—																		
1910	65- 0	62	3- 0	4	0-14	1	0-13	1	3-10	4	12- 1	13	13- 3	13	31- 7	26		
1911	112-13	115	8-11	12	11- 9	14	6-11	8	22- 6	24	24- 5	24	8- 8	8	30-11	25		
1912	135-15	159	24- 2	38	12- 3	16	19-12	24	22- 6	25	15-11	17	18- 4	18	23- 9	21	1.67	
1913	74-10	93	20- 0	30	22-11	29	8- 4	10	12- 2	13	6- 0	6	4- 6	4	1- 3	1	0	
1914	63- 0	88	39-15	61	10- 8	13	7-12	9	3-12	4	0- 0	0	1- 1	1	0- 0	0	6.33	
1915	46-11	46	6-12	9	2-10	3	3-13	4	9- 0	9	8-11	8	4- 9	4	11- 4	9	5.33	
Average	83.0	94	17.1	26	10.1	13	7.8	9	12.2	13	11.1	11	8.3	8	16.4	14	3.33	
Standard grade—																		
1910	21- 0	22	0-11	1	0-12	1	0- 0	0	1-13	2	2-14	3	7- 5	8	7- 9	7		
1911	44- 4	57	16- 9	27	4-12	6	5-14	7	5- 2	6	4- 0	4	2-15	3	5- 0	4		
1912	48-15	58	6- 1	10	6-10	9	7- 0	9	9-13	11	5- 9	6	6-15	7	6-15	6	2.67	
1913	34- 5	47	18-14	29	7- 5	9	5- 4	6	1-13	2	1- 1	1	0- 0	0	0- 0	0	2.00	
1914	34- 4	50	21- 0	34	8-12	11	1-11	2	2-13	3	0- 0	0	0- 0	0	0- 0	0	4.67	
1915	21- 8	22	4-14	7	0- 0	0	1-13	2	3- 0	3	4- 5	4	1- 2	1	6- 6	5	5.00	
Average	34.0	43	11.3	18	4.7	6	3.6	4	4.1	5	3.0	3	3.1	3	4.3	3	3.59	
Cull fruits—																		
1912	4- 8	6																
1913	10- 5	36																
1914	12- 0	22															3.00	
1915	2- 7	3															1.00	
Average	7.3	17															2.00	
Total crop—																		
1910	86- 0	84	3-11	5	1-10	2	0-13	1	5- 7	6	14-15	16	20- 8	21	39- 0	33		
1911	157- 1	172	25- 4	39	16- 5	20	12- 9	15	27- 8	30	28- 5	28	11- 7	11	35-11	29		
1912	189- 6	223	30- 3	48	18-13	25	26-12	33	32- 3	36	21- 4	23	25- 3	25	30- 8	27	2.33	2
1913	119- 4	176	38-14	59	30- 0	38	13- 8	16	13-15	15	7- 1	7	4- 6	4	1- 3	1	.80	1
1914	109- 4	160	60-15	95	19- 4	24	9- 7	11	6- 9	7	0- 0	0	1- 1	1	0- 0	0	4.67	3
1915	70-10	71	11-10	16	2-10	3	5-10	6	12- 0	12	13- 0	12	5-11	5	17-10	14	4.00	2
Average	**121.9**	**148**	**28.4**	**44**	**14.8**	**19**	**11.4**	**14**	**16.3**	**18**	**14.1**	**14**	**11.4**	**11**	**20.7**	**17**	**2.95**	**2.00**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
46. Tree No. 23-63-22, Alternate-Bearing strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	69- 6	90	18- 3	28	8-12	12	17- 9	22	12-14	15	8-14	10	2- 1	2	1- 1	1	....	....
1911	35- 8	23	0- 0	0	0- 0	0	0- 0	0	1-11	2	2- 3	2	3- 3	3	28- 7	16	....	....
1912	113- 3	155	47- 6	75	20- 0	27	21- 1	26	10- 4	12	7- 6	8	4- 0	4	3- 2	3	3.00	....
1913	86- 3	94	7-13	12	6-15	9	9- 6	11	28- 9	31	9- 1	9	12- 9	12	11-14	10	0	....
1914	77- 1	101	37- 4	54	14- 6	18	12- 1	14	13- 6	15	0- 0	0	0- 0	0	0- 0	0	5.33	....
1915	40- 1	40	4-15	7	1-11	2	7- 8	8	8- 3	8	7-12	7	4-12	4	5- 4	4	5.33	....
Average	70.2	84	19.3	29	8.6	11	11.3	14	12.5	14	5.8	6	4.4	4	8.3	6	3.42	....
Standard grade—																		
1910	47- 3	66	9-13	17	5- 2	8	18- 1	24	10- 5	13	3-14	4	0- 0	0	0- 0	0	....	....
1911	6- 2	5	0- 0	0	0- 0	0	0- 0	0	0- 0	0	0- 0	0	2- 4	2	3-14	3	....	....
1912	92- 7	127	38- 6	64	15-10	21	13- 6	16	10- 9	12	6-10	7	5-12	5	2- 2	2	2.83	....
1913	57- 3	69	16-13	26	7- 2	9	6-14	8	12- 3	13	5- 2	5	3- 3	3	5-14	5	2.00	....
1914	48- 3	66	25- 7	39	6- 6	8	11-14	14	4- 8	5	0- 0	0	0- 0	0	0- 0	0	6.33	....
1915	17- 5	17	1- 7	2	0-14	1	2-9	3	5- 1	5	2- 3	2	2- 6	2	2-13	2	6.67	....
Average	44.7	58	15.3	25	5.8	8	8.8	10	7.1	8	3.0	3	2.3	2	2.4	2	4.46	....
Cull fruits—																		
1912	2- 4	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	11-11	32	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	12- 6	32	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.00	....
1915	1- 0	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.50	....
Average	6.8	18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.75	....

Total crop—																		
1910	116– 9	156	28– 0	45	13–14	20	35–10	46	23– 3	28	12–12	14	2– 1	2	1– 1	1	....	....
1911	41–10	28	0– 0	0	0– 0	0	0– 0	0	1–11	2	2– 3	2	5– 7	5	32– 5	19	....	....
1912	207–14	287	85–12	139	35–10	48	34– 7	42	20–13	24	14– 0	15	9–12	9	5– 4	5	2.89	0
1913	155– 1	195	24–10	38	14– 1	18	16– 4	19	40–12	44	14– 3	14	15–12	15	17–12	15	1.00	0
1914	137–10	199	62–11	93	20–12	26	23–15	28	17–14	20	0– 0	0	0– 0	0	0– 0	0	5.89	0
1915	58– 6	59	6– 6	9	2– 9	3	10– 1	11	13– 4	13	9–15	9	7– 2	6	8– 1	6	4.88	0
Average	**119.5**	**154**	**34.6**	**54**	**14.5**	**19**	**20.1**	**24**	**19.6**	**22**	**8.8**	**9**	**6.7**	**6**	**10.7**	**8**	**3.67**	**0**
47. Tree No. 23-63-16, Marsh strain:																		
Ivory-White grade—																		
1910	88– 9	101	11– 5	17	4–15	7	15–11	19	16– 0	18	10– 1	11	12–15	13	17–10	16	....	....
1911	122–13	133	15– 8	23	9–10	12	16– 6	19	20– 4	22	19–10	20	23–13	22	17–10	15	....	....
1912	92–13	112	17–12	29	9–11	13	12– 4	15	18– 7	21	15– 7	16	11– 6	11	7–14	7	1.33	....
1913	71– 8	89	17– 4	26	16– 4	21	13– 8	16	12–11	14	6–12	7	5– 1	5	0– 0	0	2.33	....
1914	52– 9	83	45– 5	74	5– 9	7	0–12	1	0–15	1	0– 0	0	0– 0	0	0– 0	0	2.00	....
1915	40– 5	43	8–10	11	5–14	7	5–12	6	7–14	8	7– 7	7	3– 8	3	1– 4	1	5.00	....
Average	78.1	94	19.3	30	8.7	11	10.7	13	12.7	14	9.9	10	9.4	9	7.4	6	3.92	....
Standard grade—																		
1910	51–11	66	8– 2	15	2– 9	4	9– 3	12	8– 3	10	6– 1	7	9– 6	10	8– 3	8	....	....
1911	42– 2	48	6–15	11	5– 8	7	4– 4	5	5– 8	6	5– 9	6	8– 7	8	5–15	5	....	....
1912	52–14	65	9– 2	16	6– 6	8	14– 2	17	7– 1	8	4–14	5	8– 0	8	3– 5	3	.17	....
1913	22–11	33	12– 4	21	4–14	6	1–12	2	1–12	2	0–15	1	1– 2	1	0– 0	0	2.33	....
1914	26– 6	41	21– 9	35	3–15	5	0– 0	0	0–14	1	0– 0	0	0– 0	0	0– 0	0	6.00	....
1915	11– 5	13	5– 5	7	0–14	1	0–15	1	2–15	3	0– 0	0	0– 0	0	1– 4	1	3.67	....
Average	34.5	44	10.5	18	4.0	5	5.1	6	4.4	5	2.9	3	4.5	5	3.1	3	3.04	....
Cull fruits—																		
1912	9– 7	13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	7– 4	16	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	14– 5	35	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.33	....
1915	0– 0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Average	7.8	16	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.33	....
Total crop—																		
1910	140– 4	167	19– 7	32	7– 8	11	24–14	31	24– 3	28	16– 2	18	22– 5	23	25–13	24	....	....
1911	164–15	181	22– 7	34	15– 2	19	20–10	24	25–12	28	25– 3	26	32– 4	30	23– 9	20	....	....
1912	155– 2	190	26–14	45	16– 1	21	26– 6	32	25– 8	29	20– 5	21	19– 6	19	11– 3	10	.55	2
1913	101– 7	138	29– 8	47	21– 2	27	15– 4	18	14– 7	16	7–11	8	6– 3	6	0– 0	0	2.33	0
1914	93– 4	159	66–14	109	9– 8	12	0–12	1	1–13	2	0– 0	0	0– 0	0	0– 0	0	5.78	2
1915	51–10	56	13–15	18	6–12	8	6–11	7	10–13	11	7– 7	7	3– 8	3	2– 8	2	4.33	1
Average	**117.8**	**149**	**29.8**	**48**	**12.7**	**16**	**15.8**	**19**	**17.1**	**19**	**12.8**	**13**	**13.9**	**14**	**10.5**	**9**	**3.25**	**1.25**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
48. **Tree No. 23-65-19,** Marsh strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	112- 7	134	18-11	29	9- 7	13	14- 2	18	30-14	35	13- 1	14	12-12	13	12-14	12	....	....
1911	88-10	96	13-10	18	10-15	13	13-12	16	17-12	19	14- 4	14	6- 8	6	11-13	10	....	....
1912	110- 3	122	11-10	18	9- 4	12	12- 8	15	20-12	23	19- 9	21	14-11	14	21-13	19	0.67	....
1913	61- 0	68	8- 9	13	8-14	11	7-10	9	12-14	14	7-14	8	8- 0	7	7- 3	6	.33	....
1914	50- 1	76	39- 4	63	6- 7	8	2- 9	3	1-13	2	0- 0	0	0- 0	0	0- 0	0	5.33	....
1915	30- 0	31	3-14	5	0-15	1	8- 2	9	7-14	8	3- 3	3	4-12	4	1- 4	1	5.33	....
Average	75.4	88	15.9	24	7.7	10	9.8	12	15.3	17	9.7	10	7.8	7	9.2	8	2.92	....
Standard grade—																		
1910	48- 1	67	9-10	18	5-12	9	9- 0	12	6-14	9	5-15	7	7- 4	8	3-10	4	....	....
1911	53- 1	58	6-14	10	4- 2	5	7-14	9	17- 0	18	6-10	7	2- 1	2	8- 8	7	....	....
1912	60-10	66	6- 4	9	5- 6	7	8- 3	10	10- 1	11	12-11	13	5- 4	5	12-13	11	.17	....
1913	22- 6	30	6-13	14	2- 7	3	4- 2	5	2-13	3	2- 3	2	1- 4	1	2-12	2	3.00	....
1914	27- 4	43	20-14	35	3-14	5	2- 8	3	0- 0	0	0- 0	0	0- 0	0	0- 0	0	4.67	....
1915	18-11	22	7-10	11	1-12	2	2- 0	2	4- 2	4	2- 2	2	1- 1	1	0- 0	0	5.50	....
Average	38.3	48	9.7	16	3.9	5	5.6	7	6.8	7	4.9	5	2.8	3	4.6	4	3.34	....
Cull fruits—																		
1912	6- 1	8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	3-11	11	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	14-10	33	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.33	....
1915	0- 0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Average	6.1	13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.33	....

Total crop—																		
1910	160– 8	201	28– 5	47	15–13	22	23– 2	30	37–12	44	19– 0	21	20– 0	21	16– 8	16	....	....
1911	141–11	154	20– 8	28	15– 1	18	21–10	25	34–12	37	20–14	21	8– 9	8	20– 5	17	....	....
1912	176–14	196	17–14	27	14–10	19	20–11	25	30–13	34	32– 4	34	19–15	19	34–10	30	.33	0
1913	87– 1	109	15– 6	27	11– 5	14	11–12	14	15–11	17	10– 1	10	9– 4	8	9–15	8	1.67	1
1914	91–15	152	60– 2	98	10– 5	13	5– 1	6	1–13	2	0– 0	0	0– 0	0	0– 0	0	5.11	2
1915	48–11	53	11– 8	16	2–11	3	10– 2	12	12– 0	12	5– 5	5	5–13	5	1– 4	1	5.40	2
Average	117.8	144	25.6	41	11.6	15	15.4	19	22.1	24	14.6	15	10.6	10	13.8	12	3.13	1.25
49. Tree No. 23-63-19, Marsh strain:																		
Ivory-White grade—																		
1910	98– 3	121	29– 4	43	11– 9	15	12– 4	15	13–12	16	16– 4	17	8–13	9	6– 5	6	....	....
1911	165–10	172	6– 0	8	7– 9	9	21– 4	23	22– 2	22	28–12	27	12–12	29	67– 3	54	....	....
1912	98– 1	108	20–11	31	6– 5	8	14– 0	16	9– 6	10	12– 1	12	15– 4	14	20– 6	17	1.67	....
1913	31–11	39	8–10	14	5–13	7	5– 1	6	3– 9	4	4– 2	4	3– 4	3	1– 4	1	.67	....
1914	31– 7	43	19– 6	29	5–10	7	2–10	3	1–14	2	1–15	2	0– 0	0	0– 0	0	6.67	....
1915	68– 6	65	2– 8	3	4– 5	5	5– 8	6	16–13	17	16– 1	15	10– 7	9	12–12	10	5.33	....
Average	82.2	91	14.4	21	6.9	8	10.1	11	11.3	12	13.2	13	8.4	11	18.0	15	3.59	....
Standard grade—																		
1910	36–14	54	16– 2	28	4– 1	5	4– 4	6	5– 7	7	4–14	6	2– 2	2	0– 0	0	....	....
1911	21– 0	30	8– 1	16	0– 0	0	4– 6	5	3–11	4	0–12	1	0–13	1	3– 5	3	....	....
1912	20–11	22	0– 0	0	3– 1	4	4– 6	5	2–11	3	2–13	3	4– 6	4	3– 6	3	3.75	....
1913	13– 1	21	7– 6	15	0–13	1	1–12	2	1– 0	1	1– 1	1	1– 1	1	0– 0	0	3.50	....
1914	29– 4	43	22– 9	35	3– 2	4	2–10	3	0–15	1	0– 0	0	0– 0	0	0– 0	0	4.33	....
1915	33– 7	32	2– 7	3	2– 9	3	1–15	2	5– 0	5	10–14	10	3– 7	3	7– 3	6	5.33	....
Average	25.7	34	9.4	16	2.2	3	3.2	4	3.1	3	3.4	3	2.0	2	2.3	2	4.23	....
Cull fruits—																		
1912	5– 6	7	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	4– 6	21	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	18– 4	37	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.67	....
1915	0– 0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Average	7.0	16	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.67	....
Total crop—																		
1910	135– 1	175	45– 6	71	15–10	20	16– 8	21	19– 3	23	21– 2	23	10–15	11	6– 5	6	....	....
1911	186–10	202	14– 1	24	7– 9	9	25–10	28	25–13	26	29– 8	28	13– 9	30	70– 8	57	....	....
1912	124– 2	137	20–11	31	9– 6	12	18– 6	21	12– 1	13	14–14	15	19–10	18	23–12	20	2.89	0
1913	49– 2	81	16– 0	29	6–10	8	6–13	8	4– 9	5	5– 3	5	4– 5	4	1– 4	1	1.80	0
1914	78–15	123	41–15	64	8–12	11	5– 4	6	2–13	3	1–15	2	0– 0	0	0– 0	0	5.89	1
1915	101–13	97	4–15	6	6–14	8	7– 7	8	21–13	22	26–15	25	13–14	12	19–15	16	5.33	0
Average	112.6	136	23.8	38	9.1	11	13.3	15	14.4	15	16.6	16	10.4	13	20.3	17	3.98	0.25

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive.*

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
50. Tree No. 23–63–25, Unproductive strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	68–5	82	15–2	23	4–7	6	8–14	11	20–0	22	11–5	12	6–6	6	2–3	2	....	....
1911	110–11	98	2–3	3	2–10	3	10–4	11	10–13	11	11–7	11	24–0	21	49–6	38	....	....
1912	59–15	58	4–11	7	1–6	2	4–3	5	2–12	3	4–1	4	10–8	10	32–6	27	1.33	....
1913	73–15	88	11–3	18	17–4	22	15–5	18	14–12	16	6–2	6	3–5	3	6–0	5	0	....
1914	69–13	97	45–14	69	9–0	11	8–8	10	6–7	7	0–0	0	0–0	0	0–0	0	5.33	....
1915	34–11	35	4–15	7	4–6	5	3–11	4	3–0	3	6–7	6	2–3	2	10–1	8	3.67	....
Average	69.6	76	14.0	21	6.5	8	8.5	10	9.6	11	6.6	7	7.7	7	16.7	13	2.58	....
Standard grade—																		
1910	26–5	37	5–7	11	1–10	2	3–6	5	8–1	10	4–14	6	0–14	1	2–1	2	....	....
1911	39–0	40	4–6	7	3–7	4	9–3	10	4–14	5	3–4	3	3–7	3	10–7	8	....	....
1912	35–10	37	5–4	8	0–0	0	4–8	5	4–10	5	5–14	6	5–5	5	10–1	8	2.17	....
1913	22–6	27	7–11	11	4–4	5	3–9	4	5–14	6	1–0	1	0–0	0	0–0	0	3.50	....
1914	25–11	36	15–10	24	4–12	6	2–7	3	2–14	3	0–0	0	0–0	0	0–0	0	4.00	....
1915	17–15	18	4–0	5	2–10	3	0–14	1	3–1	3	3–6	3	0–0	0	4–0	3	4.33	....
Average	27.8	33	7.1	11	2.8	4	4.0	4	4.9	5	3.0	3	1.6	2	4.4	3	3.50	....
Cull fruits—																		
1912	1–11	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....		....
1913	6–2	23	....	....	....	....	....	....	....	....	....	....	....	....	....	....		....
1914	13–9	28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.00	....
1915	1–12	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.33	....
Average	5.7	14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.17	....

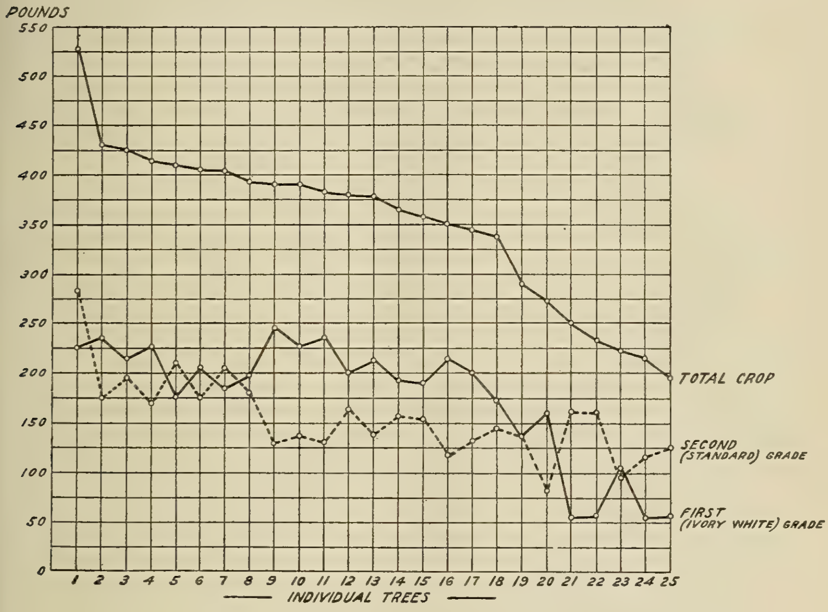
Total crop—																		
1910	94-10	119	20- 9	34	6- 1	8	12- 4	16	28- 1	32	16- 3	18	7- 4	7	4- 4	4	....	....
1911	149-11	138	6- 9	10	6- 1	7	19- 7	21	15-11	16	14-11	14	27- 7	24	59-13	46	....	....
1912	97- 4	97	9-15	15	1- 6	2	8-11	10	7- 6	8	9-15	10	15-13	15	42- 7	35	1.89	0
1913	102- 7	138	18-14	29	21- 8	27	18-14	22	20-10	22	7- 2	7	3- 5	3	6- 5	0	1.40	0
1914	109- 1	161	61- 8	93	13-12	17	10-15	13	9- 5	10	0- 0	0	0- 0	0	0- 0	0	4.77	0
1915	54- 6	56	8-15	12	7- 0	8	4- 9	5	6- 1	6	9-13	9	2- 3	2	14- 1	11	3.78	1
Average	**101.2**	**118**	**21.1**	**32**	**9.3**	**12**	**12.5**	**14**	**14.5**	**16**	**9.6**	**10**	**9.3**	**9**	**21.1**	**16**	**2.96**	**0.25**
51. Tree No. 23-60-14, Unproductive strain:																		
Ivory-White grade—																		
1910	18- 3	16	0- 9	1	0-12	1	0-14	1	0- 0	0	0- 0	0	2- 4	2	13-12	11	....	....
1911	102- 7	116	13- 5	20	12-12	16	19-11	23	24-11	27	7-15	8	9- 2	9	14-15	13	....	....
1912	58- 2	50	0-10	1	1- 8	2	2- 8	3	1- 0	1	3-14	4	8- 4	8	40- 6	31	1.67	....
1913	74- 8	88	11- 4	17	12- 6	16	12-13	16	11- 6	13	12- 8	13	8- 8	8	5-11	5	.67	....
1914	47- 6	64	22- 4	34	8- 8	11	6-10	8	8- 2	9	1-14	2	0- 0	0	0- 0	0	5.33	....
1915	40-11	41	5- 4	7	4- 8	5	4-10	5	7- 3	7	8-12	8	9- 2	8	1- 4	1	5.67	....
Average	56.9	63	8.9	13	6.7	9	7.8	9	8.7	10	5.8	6	6.2	6	12.7	10	3.34	....
Standard grade—																		
1910	15- 3	17	2-11	4	1- 9	2	0- 0	0	3-10	4	3-13	4	2- 2	2	1- 6	1	....	....
1911	40-14	50	9-15	15	12-16	16	2-20	4	4- 8	5	2-15	3	4-14	5	2- 6	2	....	....
1912	35- 1	33	0- 0	0	0- 0	0	3- 6	4	1-12	2	5-11	6	2-14	3	21- 6	18	0	....
1913	27- 3	37	7-13	16	3-13	5	2- 8	3	2-10	3	4- 0	4	3- 0	3	3- 7	3	1.33	....
1914	31- 2	46	17- 6	30	3-10	5	1-10	2	5- 8	6	3- 0	3	0- 0	0	0- 0	0	2.67	....
1915	23-10	24	2- 8	4	1-13	2	5-12	6	5- 4	5	4- 7	4	2- 7	2	1- 7	1	6.33	....
Average	28.8	35	6.7	12	4.0	5	2.8	4	3.9	4	4.0	4	2.6	2	5.0	4	2.58	....
Cull fruits—																		
1912	0- 0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	7-13	35	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	5- 3	12	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.00	....
1915	3-11	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.00	....
Average	4.2	13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.50	....
Total crop—																		
1910	33- 6	33	3- 4	5	2- 5	3	0-14	1	3-10	4	3-13	4	4- 6	4	15- 2	12	....	....
1911	143- 5	166	23- 4	35	25-12	32	22-15	27	29- 3	32	10-14	11	14- 0	14	17- 5	15	....	....
1912	93- 3	83	0-10	1	1- 8	2	5-14	7	2-12	3	9- 9	10	11- 2	11	61-12	49	.71	0
1913	109- 8	160	19- 1	33	16- 3	21	15- 5	19	14- 0	16	16- 3	17	11- 8	11	9- 2	8	1.00	1
1914	83-11	122	39-10	64	12- 2	16	8- 4	10	13-10	15	4-14	5	0- 0	0	0- 0	0	4.33	1
1915	68- 0	70	7-12	11	6- 5	7	10- 6	11	12- 7	12	13- 3	12	11- 9	10	2-11	2	5.33	0
Average	**88.5**	**106**	**15.6**	**25**	**10.7**	**14**	**10.6**	**13**	**12.6**	**14**	**9.8**	**10**	**8.8**	**8**	**17.7**	**14**	**2.84**	**0.50**

TABLE III.—*Detailed statement of the annual performance of Marsh grapefruit trees in investigational plats A and B, for which records were obtained for the 6-year period, 1910 to 1915, inclusive*—Continued.

INVESTIGATIONAL PERFORMANCE RECORD, PLAT B, PLANTED IN THE AUTUMN OF 1903—Continued.

Rank, tree No., strain, grade, and year.	Sizes.																Number of—	
	Total.		112 and smaller.		96		80		64		48		32		24 and larger.		Seeds per fruit.	Variable fruits.
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.		
52. Tree No. 23-60-15, Unproductive strain:																		
Ivory-White grade—	*Lbs. oz.*		*Lbs.toz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*			
1910	7- 2	6	0- 0	0	0-12	1	0- 0	0	0- 0	0	0- 0	0	0- 0	0	6- 6	5	....	....
1911	123- 1	131	17- 4	23	18- 9	22	11- 5	13	21- 9	23	15- 3	15	17- 0	16	22- 3	19	....	....
1912	44- 5	41	0- 0	0	3- 3	4	1-12	2	6-14	7	2-14	3	4- 4	4	25- 6	21	1.33	....
1913	59-13	74	15- 8	24	11-10	15	8- 9	10	11-11	13	8- 1	8	2- 1	2	2- 5	2	2.00	....
1914	36- 9	48	17- 3	26	9- 5	12	2-10	3	3-12	4	3- 1	3	0- 0	0	0- 0	0	8.67	....
1915	43- 2	43	6- 2	8	3- 8	4	10- 2	10	7- 2	7	7-11	7	4-11	4	3-14	3	5.00	....
Average	52.3	57	9.3	13	7.9	10	5.8	6	8.5	9	6.2	6	4.7	4	10.0	8	4.25	....
Standard grade—																		
1910	6-14	8	2- 0	3	0- 0	0	0-14	1	0-14	1	0- 0	0	2- 2	2	1- 0	1	....	....
1911	22- 4	29	8-12	13	6- 2	8	1-10	2	0-12	1	1-14	2	2- 0	2	1- 2	1	....	....
1912	37- 8	34	0- 0	0	1- 8	2	2- 7	3	3-11	4	2- 1	2	7-12	7	20- 1	16	2.00	....
1913	29-11	41	12- 4	22	2- 5	3	4- 4	5	4-10	5	4- 1	4	2- 3	2	0- 0	0	2.50	....
1914	20-14	28	9-10	15	3-14	5	3-10	4	1-13	2	1-15	2	0- 0	0	0- 0	0	4.00	....
1915	24-13	25	3-12	5	1-11	2	3- 0	3	6- 1	6	3- 5	3	3- 7	3	3- 9	3	5.67	....
Average	23.7	28	6.1	10	2.6	3	2.6	3	3.0	3	2.2	2	2.9	3	4.3	4	3.54	....
Cull fruits—																		
1912	3-15	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	6- 6	33	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	6- 2	10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.33	....
1915	3- 9	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.00	....
Average	5.0	13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.17	....
Total crop—																		
1910	14- 0	14	2- 0	3	0-12	1	0-14	1	0-14	1	0- 0	0	2- 2	2	7- 6	6	....	....
1911	145- 5	160	26- 0	36	24-11	30	12-15	15	22- 5	24	17- 1	17	19- 0	18	23- 5	20	....	....
1912	85-12	80	0- 0	0	4-11	6	4- 3	5	10- 9	11	4-15	5	12- 0	11	45- 7	37	1.78	0
1913	95-14	148	27-12	46	13-15	18	12-13	15	16- 5	18	12- 2	12	4- 4	4	2- 5	2	2.20	0
1914	63- 9	86	26-13	41	13-13	17	6- 4	7	5- 9	6	5- 0	5	0- 0	0	0- 0	0	5.67	0
1915	71- 8	73	9-14	13	5- 3	6	13- 2	13	13- 3	13	11- 0	10	8- 2	7	7- 7	6	5.00	2
Average	**79.3**	**94**	**15.4**	**23**	**10.5**	**13**	**8.4**	**9**	**11.5**	**12**	**8.4**	**8**	**7.6**	**7**	**14.3**	**12**	**3.66**	**0.50**

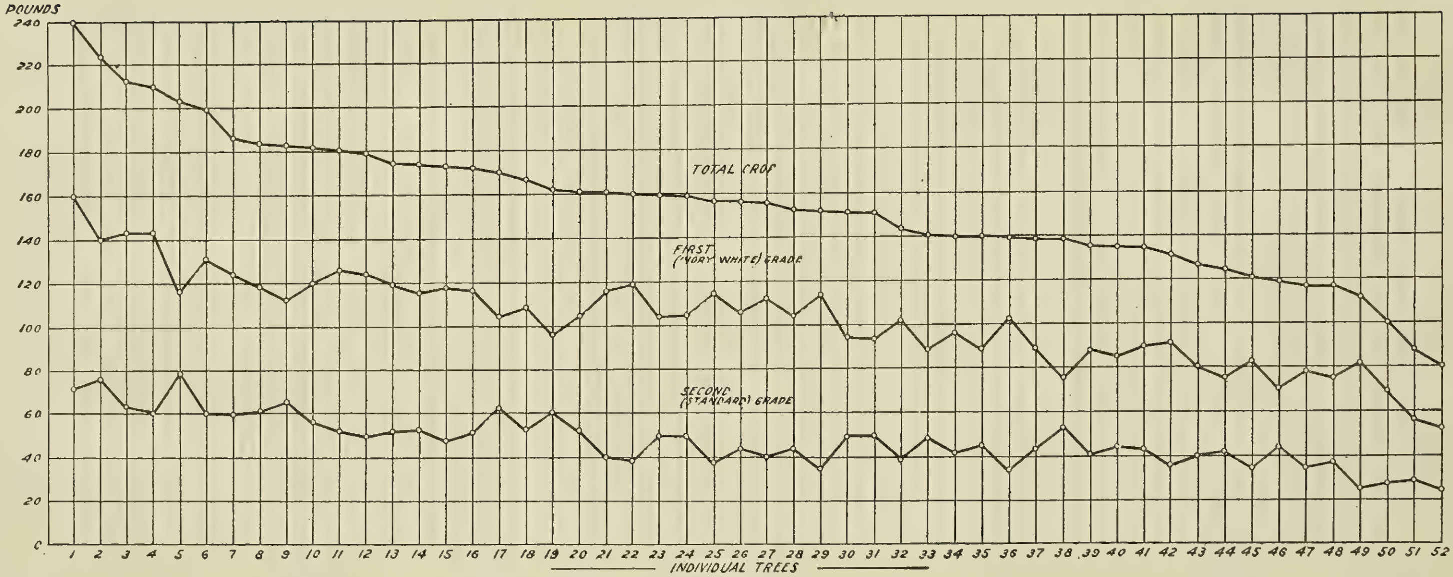
Because, as already stated, it is almost impossible, on the basis of performance records alone, to make an intelligent estimate of the relative value of different trees in any group, except of those which vary greatly in the amount of their production, no discussion of that nature will be attempted here. The records of the individual trees are presented to show the variations that occur between them. Conclusions of relative values are limited to comparisons of the various strains and the groups of highest and lowest producing trees in the two plats.



P20921HP

FIG. 1.—Average annual total crop and the production by the two commercial grades from the individual trees in the investigational performance-record plat A of Marsh grapefruit in a grove planted in 1898, being a summary of data secured during the 6-year period, 1910 to 1915, inclusive.

In order to show more clearly the relative variations in production that occur in the crops from the individual trees, figures 1 and 2 are presented, showing graphically the average total annual production of each tree and the production of the two commercial grades. The trees are ranked in these diagrams in the same order as in Table III. While the average production of the 25 trees in plat A, shown in figure 1, varies from 528.1 to 195.8 pounds, 17 of them, or 68 per cent, are seen to be within the comparatively uniform range of 430.9 to 337 pounds. The five lowest producing trees in this plat are all of the Seedy strain. The trees in plat B, recorded in figure 2, are younger than those in plat A, hence their average production is much lower. Their range of variation is from 240.1 to 79.3 pounds.



P20926HP

FIG. 2.—Average total annual crop and the production by the two commercial grades of the individual trees of Marsh grapefruit in the investigational performance-record plat B in a grove planted in the fall of 1903, being a summary of data secured during the 6-year period, 1910 to 1915, inclusive.

However, 42 of them, or 80.8 per cent, are within the comparatively uniform limits between 186.8 and 117.8 pounds. The three lowest producing trees in this plat are of the Unproductive strain.

Table IV shows the proportions of first-grade fruit in the crops of each tree in the investigational plats during the 6-year period, 1910 to 1915, inclusive, and the percentages of variable fruits which were recorded from each tree during the four years, 1912 to 1915, inclusive.

TABLE IV.—*Average annual production of the individual Marsh grapefruit trees in investigational plats A and B, for which detailed performance records were obtained for the 6-year period, 1910 to 1915, inclusive.*

[The strain to which each tree belongs is shown by abbreviations as follows: AB=Alternate Bearing, M=Marsh, R=Rough, RS=Rough Seedy, SS=Smooth Seedy, U=Unproductive.]

INVESTIGATIONAL PLAT A, PLANTED IN 1898.

Rank.	Strain.	Tree No.	Average annual production.				Rank.	Strain.	Tree No.	Average annual production.			
			Weight.	Number.	First grade (by weight).	Variable fruits[1] (by number).				Weight.	Number.	First grade (by weight).	Variable fruits[1] (by number).
			Lbs.		*Per cent.*	*Per cent.*				*Lbs.*		*Per cent.*	*Per cent.*
1	M	1-14-30	528.1	668	42.6	0.75	14	M	1-16-29	363.9	444	53.0	0.39
2	M	1-16-31	430.9	539	55.0	.70	15	M	1-17-29	357.0	425	52.6	.41
3	M	1-15-30	426.4	559	50.6	.45	16	M	1-17-31	351.5	400	61.2	1.00
4	M	1-16-30	414.3	518	54.8	.19	17	M	1-17-32	342.8	430	58.6	.41
5	M	1-15-31	409.2	540	42.9	.19	18	M	1-16-33	337.0	408	51.1	.31
6	M	1-17-30	404.6	482	50.6	.21	19	M	1-15-32	289.5	415	47.3	.60
7	R	1-14-32	404.5	531	45.5	.33	20	M	1-18-33	272.4	373	59.5	.40
8	M	1-14-33	393.5	507	49.9	.20	21	RS	1-14-29	249.2	288	22.5	.61
9	M	1-18-30	391.9	444	62.8	.39	22	RS	1-14-31	232.8	274	24.2	1.00
10	M	1-17-33	391.9	508	57.6	.20	23	SS	1-18-31	222.4	248	49.3	.20
11	M	1-18-29	382.1	411	61.8	.55	24	RS	1-15-33	214.9	267	26.2	.75
12	M	1-16-32	378.8	490	53.2	.26	25	RS	1-15-29	195.8	230	28.9	.87
13	M	1-18-32	377.1	447	56.4	.17							

INVESTIGATIONAL PLAT B, PLANTED IN THE AUTUMN OF 1903.

Rank.	Strain.	Tree No.	Weight.	Number.	First grade (by weight).	Variable fruits[1] (by number).	Rank.	Strain.	Tree No.	Weight.	Number.	First grade (by weight).	Variable fruits[1] (by number).
1	M	23-59-13	240.1	299	65.9	0.33	27	M	23-59-10	156.5	182	71.3	0.41
2	M	23-59- 5	223.7	263	62.6	1.24	28	AB	23-62-13	153.3	191	68.0	.26
3	M	23-59-11	213.3	258	67.1	.39	29	M	23-61-15	152.7	180	74.7	.00
4	M	23-61-13	210.3	242	68.0	.52	30	M	23-62-17	151.6	190	62.3	.53
5	M	23-60-16	203.5	256	57.0	.39	31	AB	23-61-19	151.4	193	61.7	.52
6	M	23-60-12	199.2	229	65.8	.66	32	M	23-63-20	143.6	177	70.8	.71
7	M	23-59-15	186.8	224	66.2	.34	33	M	23-60-18	141.8	168	62.2	.74
8	M	23-61-21	184.2	228	63.8	.66	34	M	23-61-16	141.5	168	68.1	2.68
9	M	23-61-20	182.7	230	60.8	.65	35	M	23-60-13	140.1	163	63.9	.46
10	M	23-61-11	182.6	234	66.0	.21	36	M	23-63-18	139.3	156	73.8	.48
11	M	23-63-21	181.6	221	69.4	.45	37	M	23-60-17	138.9	164	64.3	.46
12	M	23-60-11	179.0	203	68.9	.86	38	M	23-62-20	138.5	168	55.1	.89
13	M	23-60- 9	175.1	217	67.4	1.04	39	M	23-62-12	135.6	170	69.9	.59
14	M	23-62-16	174.5	214	66.0	.58	40	AB	23-59-12	135.1	174	62.9	1.01
15	M	23-60- 8	173.1	207	68.4	.12	41	M	23-61-12	134.9	160	66.5	.47
16	M	23-59- 7	171.9	204	67.3	1.35	42	M	23-62-18	131.1	146	69.9	1.20
17	M	23-63-15	170.3	218	61.6	.23	43	M	23-59- 6	126.7	148	64.2	.34
18	AB	23-62-22	166.4	212	65.6	.59	44	M	23-63-23	125.1	156	60.5	.64
19	AB	23-61-18	162.9	213	58.4	.23	45	M	23-62-19	121.9	148	68.1	1.35
20	M	23-60-10	161.7	197	65.2	.25	46	AB	23-63-22	119.5	154	58.7	.00
21	M	23-59- 8	161.5	194	72.4	.77	47	M	23-63-16	117.8	149	66.3	.84
22	AB	23-61-14	159.8	194	74.4	.90	48	M	23-65-19	117.8	144	64.0	.87
23	M	23-62-21	159.8	196	65.4	.77	49	M	23-63-19	112.6	136	73.0	.18
24	M	23-59-14	159.7	190	65.8	.39	50	U	23-63-25	101.2	118	68.8	.21
25	AB	23-62-15	158.1	193	72.6	.13	51	U	23-60-14	88.5	106	64.3	.47
26	AB	23-59- 9	157.1	196	67.8	.26	52	U	23-60-15	79.3	94	66.0	.53

---

[1] These data relating to variable fruits cover only four years, 1912 to 1915, inclusive.

In Table V and the corresponding diagrams, figures 3 and 4, the trees in the two performance-record plats are grouped by strains, and the average annual production of the individuals of each group is expressed. Groups are included which comprise the five highest producing and the five lowest producing trees irrespective of their strain, and it is worthy of note that the trees showing the highest production in both plats are all of the Marsh strain. The average production of the trees of the Marsh strain is shown to be greater than the average for any other strain in the same plat. The crop of the one tree of the Rough strain in plat A can not fairly be considered comparable to the averages shown for the other strains.

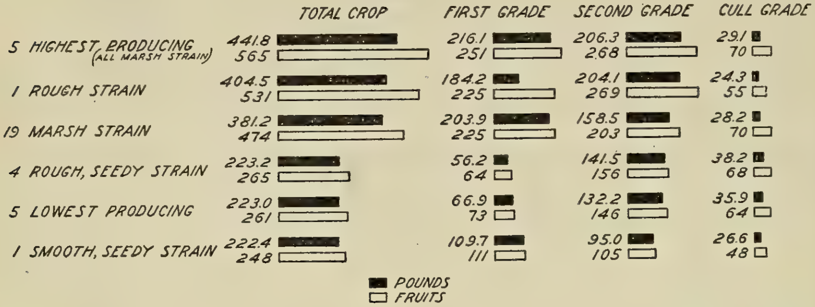


FIG. 3.—Average annual crop of the individual trees of the different strains of Marsh grapefruit occurring in the investigational performance-record plat A in a grove planted in 1898, being a summary of data for the 6-year period, 1910 to 1915, inclusive, except that the data relating to culls covers only the 4-year period, 1912 to 1915, inclusive.

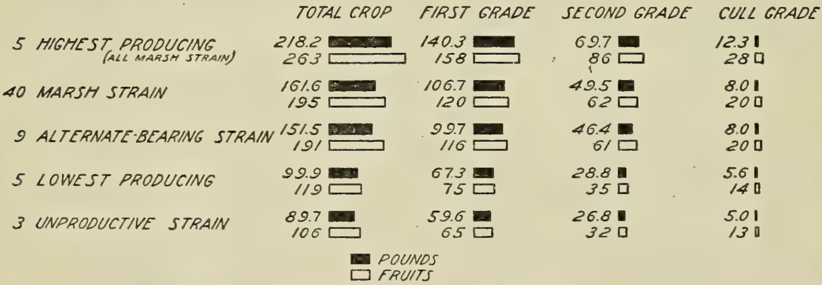


FIG. 4.—Average annual crop of the individual trees of the different strains of Marsh grapefruit occurring in the investigational performance-record plat B in a grove planted in the fall of 1903, being a summary of data for the 6-year period 1910 to 1915, inclusive, except that the data relating to culls covers only the 4-year period, 1912 to 1915, inclusive.

Figures 5 and 6 show the average annual proportions of fruit of the different grades in the crops of the trees of the various strains occurring in the investigational performance-record plats, based on the average weights of the crops for the six years, 1910 to 1915, inclusive. Figure 5 shows that in plat A the highest proportion of fruit of the first grade was produced by the trees of the Marsh strain, and this strain also bears the best quality fruit. The low proportion of first-grade fruit produced by the trees of the Rough Seedy strain was very noticeable. Figure 6 shows that in plat B there was practically no difference between the trees of the different strains in their proportions of fruit of the different grades.

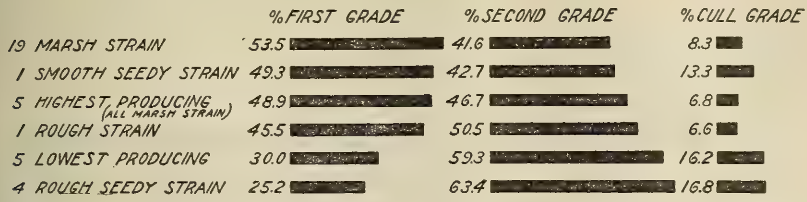


FIG. 5.—Average annual proportions of fruit of the different commercial grades in the crops of the trees of the various strains of Marsh grapefruit occurring in the investigational performance-record plat A in a grove planted in 1898. The percentages are based on the average weights of the crops for the 6-year period, 1910 to 1915, inclusive, except that the data regarding culls cover only the 4-year period, 1912 to 1915, inclusive.

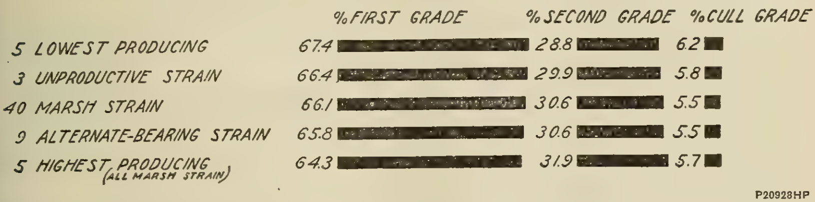


FIG. 6.—Average annual proportions of fruit of the different commercial grades in the crops of the trees of the various strains of Marsh grapefruit occurring in the investigational performance-record plat B in a grove planted in the fall of 1903. The percentages are based on the average weights of the crops for the 6-year period, 1910 to 1915, inclusive, except that the data relating to culls cover only the 4-year period, 1912 to 1915, inclusive.

TABLE V.—*Average total annual crop per tree of the different strains of Marsh grapefruit in investigational plats A and B, showing production by grades of fruit for the 6-year period, 1910 to 1915, inclusive.*

Description of trees.	Number of trees.	Average annual production.							
		Total crop.		First grade.		Second grade.		Cull grade.[1]	
		Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
Investigational plat A:									
		Lbs.		*Lbs.*		*Lbs.*		*Lbs.*	
Highest producing (all Marsh strain)	5	441.8	565	216.1	251	206.3	268	29.1	70
Rough strain	1	404.5	531	184.2	225	204.1	269	24.3	55
Marsh strain	19	381.2	474	203.9	225	158.5	203	28.2	70
Rough Seedy strain	4	223.2	265	56.2	64	141.5	156	38.2	68
Lowest producing	5	223.0	261	66.9	73	132.2	146	35.9	64
Smooth Seedy strain	1	222.4	248	109.7	111	95.0	105	26.6	48
Investigational plat B:									
Highest producing (all Marsh strain)	5	218.2	263	140.3	158	69.7	86	12.3	28
Marsh strain	40	161.6	195	106.7	120	49.5	62	8.0	20
Alternate-Bearing strain	9	151.5	191	99.7	116	46.4	61	8.0	20
Lowest producing	5	99.9	119	67.3	75	28.8	35	5.6	14
Unproductive strain	3	89.7	106	59.6	65	26.8	32	5.0	13

[1] These data relating to cull fruits cover only four years, 1912 to 1915, inclusive.

Figures 7 and 8 show the average number of seeds per fruit produced by trees of the different strains in the performance-record plats.

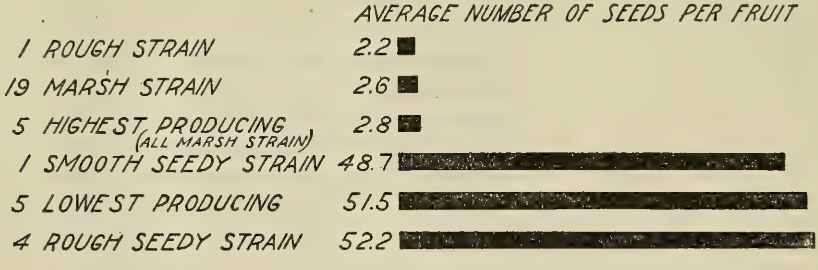


FIG. 7.—Average number of seeds per fruit found on trees of various strains of Marsh grapefruit in the investigational performance-record plat A in a grove planted in 1898, being a summary of the data secured during the 6-year period, 1910 to 1915, inclusive.

These data indicate that the most productive and most desirable strains and groups of trees bear fruit with the least number of seed. The high seed content of the fruits of the seedy strains is strikingly shown in figure 7.

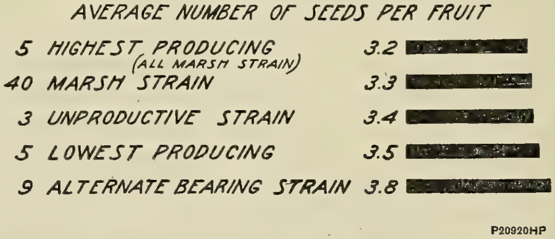


FIG. 8.—Average number of seeds per fruit found on trees of various strains of Marsh grapefruit in the investigational performance record plat B in a grove planted in the fall of 1903, being a summary of the data secured during the 4-year period, 1912 to 1915, inclusive.

Figures 9 and 10 show the percentages of fruits of a variable character found in the total crops of the trees of the various strains in the performance-record plats. Practically all of these fruits were forms of minor importance.

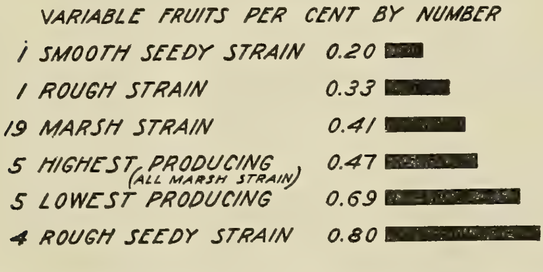


FIG. 9.—Percentage of variable fruits found on trees of various strains of the Marsh grapefruit in the investigational performance-record plat A in a grove planted in 1898, being a summary of the data secured during the 4-year period, 1912 to 1915, inclusive.

Figures 11 and 12 show the average production by weight of the different commercial sizes and grades from the five highest producing trees in each of the performance-record plats in comparison with the corresponding yields of the five lowest producing trees of these plats, respectively. These summaries are for the 6-year period, 1910 to 1915, inclusive, except that the data relating to culls cover only the four years, 1912 to 1915, inclusive. Figure 11 shows that the heaviest producing trees in plat A also bore the largest proportion of fruit of the most desirable sizes and of the Ivory-White (or first) grade. The data in figure 12 show that in plat B there was very little difference between the heaviest and lowest producing trees with respect to these same characters.

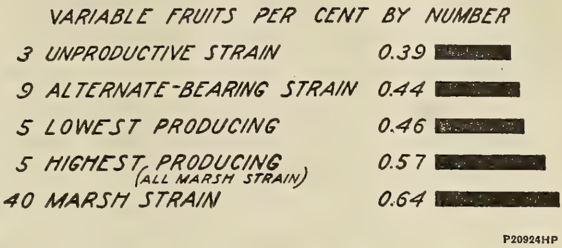


FIG. 10.—Percentage of variable fruits found on trees of various strains of the Marsh grapefruit in the investigational performance-record plat B in a grove planted in the fall of 1903, being a summary of the data secured during the 4-year period, 1912 to 1915, inclusive.

In figures 13 and 14 are shown the average number of fruits of the various commercial sizes produced during the 6-year period, 1910 to 1915, inclusive, by the five highest yielding and the five lowest yielding trees in the two performance-record plats. This production is expressed in percentages of a packed box for the fruit of each size.

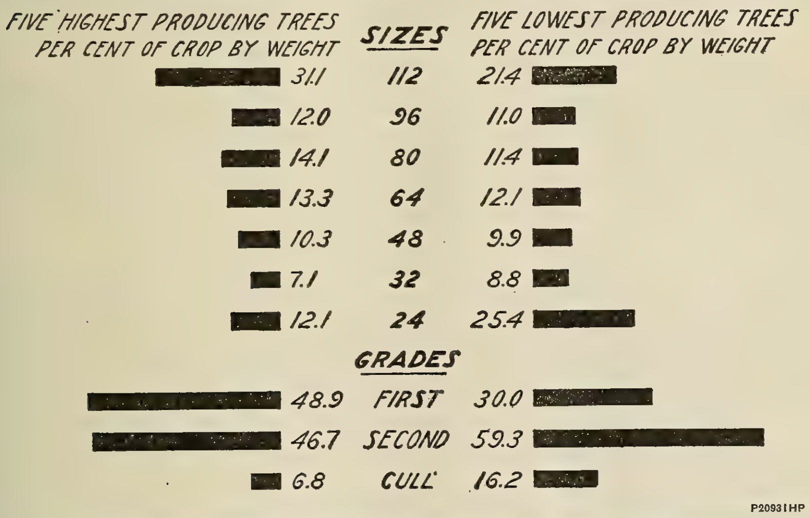


FIG. 11.—Average annual production by commercial sizes and grades from the five highest and the five lowest producing Marsh grapefruit trees, irrespective of strain, in the investigational performance-record plat A in a grove planted in 1898. The figures indicate the proportion of each size and grade to the total crop, calculated from their weights during the 6-year period, 1910 to 1915, inclusive, except that the data relating to culls cover only the 4-year period, 1912 to 1915, inclusive.

The yield on the acre basis is figured at the rate of production of both the highest and lowest yielding trees and the actual values of those possible yields are given. The figures show that the highest producing trees bore approximately twice the crop that was borne by the lowest producing trees. The great difference in production from the trees on the two plats is largely accounted for by the difference in the ages of the trees. The difference in the value of the crops from the highest and lowest producing trees serves to emphasize the desirability of propagating only from trees with known records of heavy and valuable production.

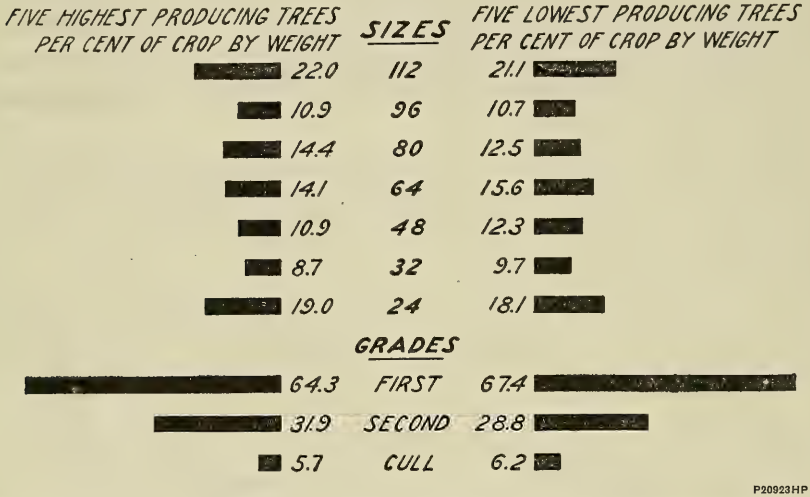


FIG. 12.—Average annual production by commercial sizes and grades from the five highest and the five lowest producing Marsh grapefruit trees, irrespective of strain, in the investigational performance-record plat B in a grove planted in the fall of 1903. The figures indicate the proportion of each size and grade to the total crop, calculated from their weights during the 6-year period, 1910 to 1915, inclusive, except that the data relating to culls cover only the 4-year period, 1912 to 1915, inclusive.

COMPARATIVE VALUE OF THE STRAINS.

The Marsh is the most productive and most valuable strain within the Marsh variety. The flattened shape of the fruits, the smooth texture and waxy-white color of the rind, the abundance of juice of high flavor and fine quality, the commercially seedless condition of the fruits, and other characteristics, all combine to make them of superior value. The regular, heavy production of the trees under favorable conditions makes this strain one of the most stable and profitable of any of the citrus fruits in California. The increasing price paid for ripe fruits of this strain in many important markets during recent years is proof of their superior value. It would seem advisable to eliminate all other strains and varieties and grow only the Marsh strain in all commercial grapefruit orchards in California.

The seedy strains are undesirable, and the presence of even occasional fruits of this character in the crops is detrimental to the reputation of the variety. Because the fruits of the Smooth Seedy strain are similar in appearance to those of the Marsh strain, but heavily seeded, the only safe way to eliminate such fruits is by top-working the trees of the seedy strains, using for this purpose buds selected from desirable trees of the Marsh strain.

Where fruits of undesirable strains are borne on particular limbs in trees of the Marsh strain, they can be eliminated by cutting out those limbs. An examination of the trees before picking will reveal the presence of any limbs bearing poor or undesirable fruits.

The Alternate-Bearing strain is usually not as valuable as the regular-bearing Marsh strain. In order to stabilize and standardize the grapefruit industry, regularity of production must be secured.

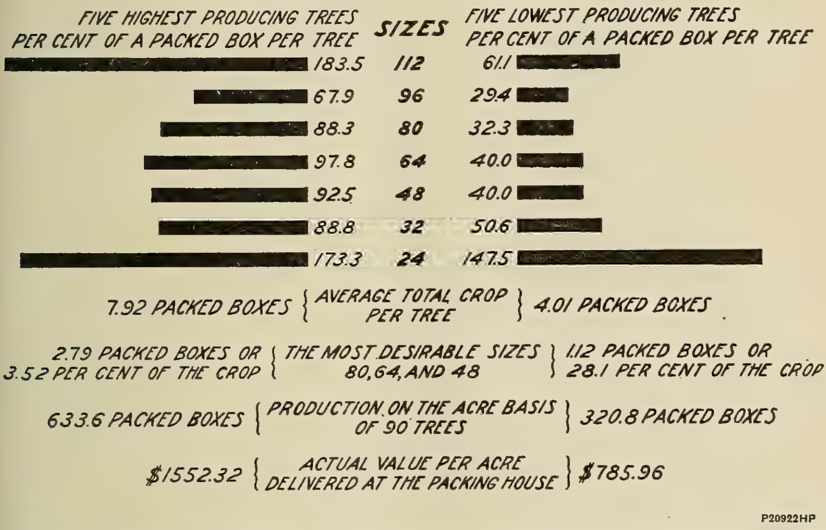


FIG. 13.—Average number of fruits of the various commercial sizes produced annually during the 6-year period 1910 to 1915, inclusive, by the five highest and the five lowest yielding trees of Marsh grapefruit in the investigational performance-record plat A in a grove planted in 1898. This production is expressed as percentages of a packed box calculated from the number of fruits of the different sizes contained in a box. The percentage of most desirable sizes is also stated, and the production on the acre basis is shown and its value calculated from the actual returns received for the fruit from this grove during the 6-year period.

The advisability of eliminating from established orchards trees having an alternate-season habit of production will depend on the amount of this production over a period of several years. If the production of the Alternate-Bearing trees is such as to be profitable, there is some question as to the desirability of top-working old established trees of this strain. If, however, the production of these Alternate-Bearing trees is unprofitable, there is no question but that they should either be removed and replaced by young trees of the Marsh strain, or, preferably, top-worked with buds selected from heavy bearing trees of the Marsh strain. Such trees, however, should never be used as parent trees from which to take propagating wood, no matter what their aggregate production may be.

Trees of the Bell, Rough, and Unproductive strains are all undesirable from the commercial standpoint, and should be eliminated in bearing orchards and avoided for propagation, except perhaps for purely experimental purposes. Fortunately, there are but few trees of these strains in most of the established California orchards of the Marsh variety, so that their elimination is a comparatively simple and inexpensive matter.

It is probable that by means of individual-tree records in bearing orchards covering two years most of the trees of inferior strains can be located, so that they can be top-worked with select buds of the Marsh strain.

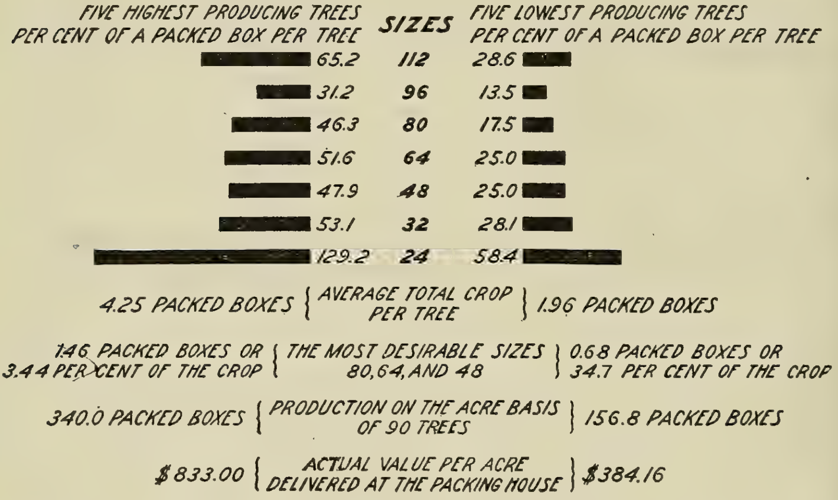


FIG. 14.—Average number of fruits of the various commercial sizes produced annually during the 6-year period, 1910 to 1915, inclusive, by the five highest and the five lowest yielding trees of Marsh grapefruit in the investigational performance-record plat B in a grove planted in the fall of 1903. This production is expressed as percentages of a packed box calculated from the number of fruits of the different sizes contained in a box. The percentage of most desirable sizes is also stated, and the production on the acre basis is shown and its value calculated from the actual returns received for the fruit from this grove during the 6-year period.

THE UNINTENTIONAL PROPAGATION OF UNDESIRABLE STRAINS.

The trees of undesirable strains in established orchards have been propagated unintentionally through a lack of careful selection of bud wood. Heretofore, all trees of the variety have been considered to be equally good for propagation, and little or no selection of trees or bud wood has been practiced.

As an illustration of this condition, the experience of the senior writer in 1910, in the first grapefruit orchard selected for individual-tree performance-record work, may be cited. In this orchard, as soon as the owner found that the seedy fruits were mainly borne by certain trees he decided to top-work those trees with select buds from trees of the Marsh strain. The senior writer was asked to select several desirable trees of this strain as sources of bud wood. Five trees were selected for this purpose and the bud wood was cut by men having had long experience in securing bud wood for propagation. After several hours' work one of these men approached the senior writer, who was working in the investigational performance-record plat near by, and said that they had been unable to obtain enough bud wood from the five trees originally selected for this purpose. He explained that, in order to secure an adequate supply, they had cut some bud wood from a neighboring tree. He was asked whether they had examined any of the fruits from this sixth tree, and he replied, "No, we never cut any fruits, but the tree looks just as good as the other five trees."

A doubt as to whether or not the additional tree was a desirable one led to an inspection of its fruits. The first fruit cut was found to contain more than 100 seeds. The production of this tree was low and the fruits of very inferior quality. Further examination showed that this tree was a typical representative of the Seedy strain, the very strain, in fact, which the workmen were preparing to eliminate by top-working. Inasmuch as the bud wood from the seedless and the seedy trees had been mixed together in the bundle of bud sticks, it was necessary to secure an entirely new lot of buds from other trees of the Marsh strain. It is interesting to note that the 118 trees of the Seedy strain top-worked in that orchard at that time have now all come into fruiting, and without exception the fruits borne by the growth from the buds of the Marsh strain are all commercially seedless and have the valuable characteristics of the fruits borne by the trees from which the buds were taken.

It can easily be seen from this experience how trees of the undesirable strains in established orchards of Marsh grapefruit have been unintentionally propagated under the old system of cutting bud wood. This experience also offers effective evidence of the need of great care in bud selection, which can be most accurately accomplished through the use of individual-tree performance records and definite tree knowledge.

THE ISOLATION OF STRAINS THROUGH BUD SELECTION.

The results of the propagation work in these investigations have proved beyond a reasonable doubt that the Marsh strain of grapefruit can be established and maintained through the careful selection of bud wood from select trees of the Marsh strain. In the course of these investigations many propagations have been made from select Marsh strain trees. Several commercial orchards have been propagated in this way. So far as these trees have come into fruiting they have all proved to be of the Marsh strain. In other words, an improved Marsh strain has been isolated and established and brought into fruiting. The trees of this improved strain are very uniform and their production is of the best grade and quality. Variation within the strain has been reduced through bud selection and from the commercial standpoint it has been eliminated. Doubtless further improvement in this strain can be effected through further bud selection in succeeding bud generations, and experiments of this character are now under way. The most important step, however, the establishment of a superior strain, has been effected. Owing to a lack of opportunity, no attempt has yet been made to isolate an inferior strain, except in the case of the seedy strains. A limited propagation of this commercially worthless strain has been made experimentally and has shown that it, too, can be isolated and established by the selection of buds from trees persistently bearing fruits of this character. There is every reason to believe that the other strains can be similarly established, and in an experimental way this work is now being done. Such propagations are of no commercial value except that they further illustrate and demonstrate the importance of careful bud selection in the propagation of the variety.

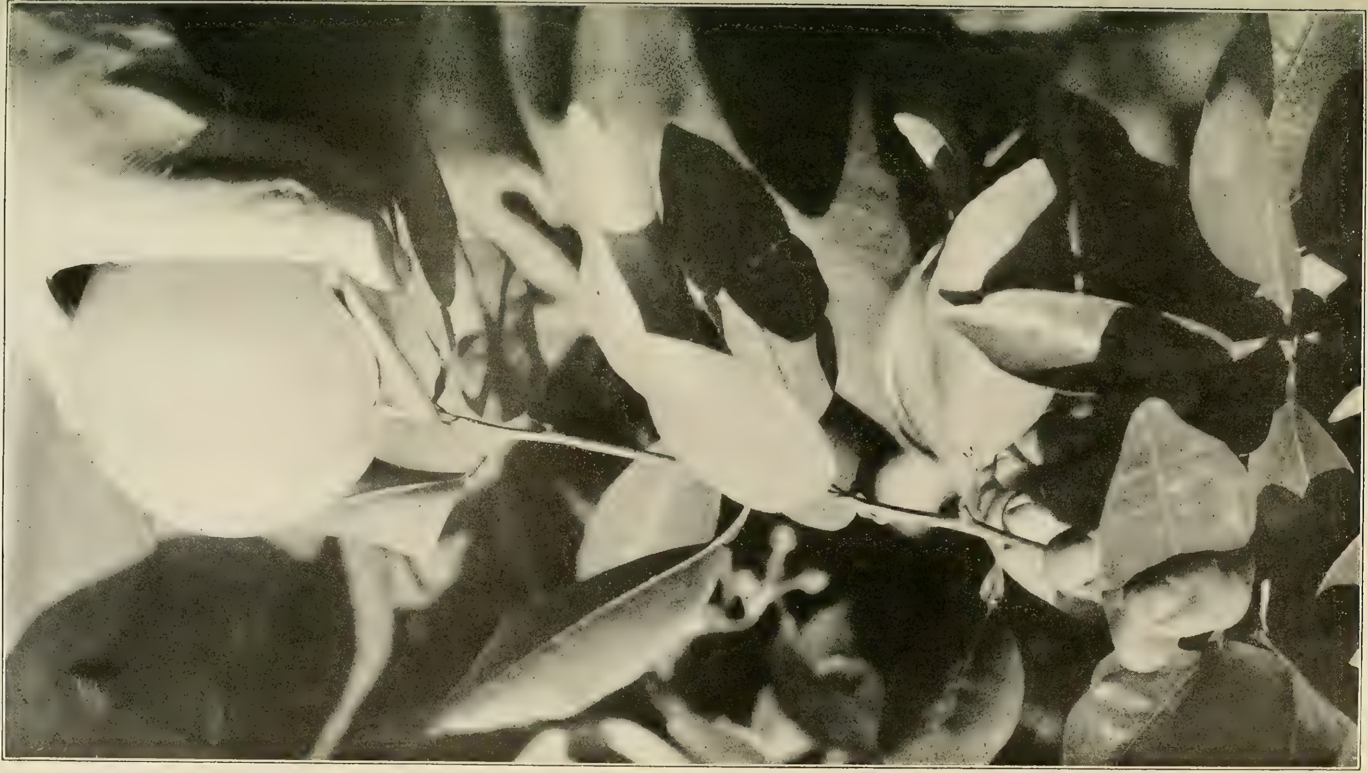
Owing to the fact that the commercial grapefruit industry in California is still in its infancy, the careful selection of buds from trees of the Marsh strain for all future propagations will likely result, throughout the State as a whole, in the development of trees of a uniform character and the production of crops of proved quality and value, an achievement unequaled in the history of any other citrus variety now grown commercially.

TOP-WORKING UNDESIRABLE TREES.

Healthy trees of undesirable strains can be successfully top-worked and replaced by the valuable Marsh strain through the use of buds selected from trees of that strain. This operation has been successfully performed on trees 12 years old. Doubtless older trees can be as successfully top-worked by the use of similar methods.

The selection of trees of the Seedy, Bell, and Rough strains for rebudding can usually be based on an inspection of the fruits. In the case of trees of the Alternate-Bearing and the Unproductive strains their selection should be based on performance records for two or more seasons, preferably an even number.

Two or more of the main limbs of the trees to be top-worked should be used as foundations for the new trees. All branches interfering with the work of budding should be cut away. The select buds should be inserted in the limbs, two or more in each, about 12 inches from the trunk of the tree. After the buds have united with



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TYPICAL FRUIT-BEARING BUD STICK FROM A SELECT MARSH GRAPEFRUIT TREE, SHOWING THE KIND OF BUD WOOD RECOMMENDED FOR USE IN PROPAGATING THIS VARIETY.

the limbs in which they were inserted the limbs should be cut off about 6 inches above the buds, and the cut surfaces should be coated with grafting wax. The tree trunks and all portions of the limbs left after the tops have been removed should be coated heavily with whitewash or other protective material, in order to prevent possible injuries due to sunburn and exposure.

From time to time all growth except that from the select buds should be carefully removed; otherwise portions of the new tree heads will be made up of sprouts from the old limbs. In some cases the tender growth from the select buds may be attacked by insect pests, in which event the insects must be promptly killed or removed. It is a good plan to protect this growth during its first exposure to winter weather by means of bundles of grass, cornstalks, or other suitable material.

After one season's growth of the select buds the stubs of the original limbs should be cut off just above the buds, making the cuts oblique in order to facilitate their healing. The cut surface should be covered with grafting wax or some other protective material, in order to prevent decay and promote the healing of the wound.

Careful attention should be given the rebudded trees for the first two or three years, in order to protect the new growth from undesirable conditions. After that such trees will require no attention or care other than that given the remainder of the trees in the orchard.

THE SELECTION OF BUD WOOD.

Bud wood for use in top-working trees of undesirable strains, or for other propagation work, should be taken from the most productive, regular-bearing trees of the Marsh strain. These trees should be selected on the basis of their performance records and the character and appearance of the individual trees. Fruit-bearing bud wood, viz, that bearing typical fruits of the kind desired, an illustration of which is shown in Plate XI, should be used exclusively for propagation purposes.

The bud wood should be packed in moist moss or other suitable material immediately after cutting, in order to preserve the buds in a fresh, viable condition until they are used. If the bud wood is to be kept for some time, it should be packed and held in a uniform, cool temperature.

Vigorous-growing, nonbearing bud wood, or that commonly known as sucker wood, has been, until recently, highly prized and commonly used for propagation purposes. Under that practice more bud wood was, of course, cut from trees having the most suckers than from the trees having the fewest suckers. It has been determined in these investigations that the trees producing the most sucker growth usually are of an undesirable strain; hence, the use of sucker wood for bud wood is probably directly responsible for much of the propagation of trees of inferior strains of the Marsh grapefruit.

SUMMARY.

The grapefruit industry in California, while of comparatively small commercial importance at present, is growing rapidly and seems likely to become an important factor in the citrus production of the State. Many of the varieties of grapefruit first planted in California proved to be of inferior commercial value. The success of the industry began with the introduction of the Marsh variety.

The Marsh variety originated at Lakeland, Fla., and was named and introduced there by Mr. C. M. Marsh, of that place, about 1895. Previous to this date, in 1890, before the variety had become established in Florida, it was introduced into California by Twogood & Cutter, of Riverside.

Bud variations in the trees of the Marsh variety of grapefruit are of frequent occurrence, and are a great commercial handicap to the growers and consumers.

Six strains arising from bud variations have been found during these investigations up to the present time.

The most valuable commercial fruits and those of the best quality are produced by trees of the Marsh strain. This strain only should be propagated for commercial purposes.

The undesirable strains which are found in commercial plantations heretofore have been propagated unintentionally through a lack of care in bud selection.

The Marsh strain can be established and maintained and variation within the strain reduced to a minimum through bud selection based on individual-tree performance records.

Healthy trees of undesirable strains can be successfully top-worked by using select buds from trees of the Marsh strain.

Only fruit-bearing bud wood should be used for propagation, and it should be selected from the most productive and otherwise most desirable trees. A practical method for locating such trees in commercial orchards is presented by the United States Department of Agriculture in Farmers' Bulletin 794, entitled "Citrus-Fruit Improvement: How to Secure and Use Tree-Performance Records."

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Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

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GRAIN-SORGHUM EXPERIMENTS IN THE PANHANDLE OF TEXAS.

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INTRODUCTION.

The agricultural development of the district known as the Panhandle of Texas is an interesting study. It is the story of four successive stages—free range, fenced range, attempts at grain farming, and finally mixed farming. In this last stage stock raising is again the basis, and the chief crops are those that furnish feed. Chief of all such crops are the sorghums, especially the grain-producing varieties.

The whole history of the grain sorghums has been a history of their ecology. Any experimental study of these crops must be a study of their response to environing conditions. The southern half of the Great Plains area, which properly may be called the grain-sorghum belt, is a section where crop production is governed almost entirely by the quantity and distribution of the annual precipitation.

The sorghums are able to produce under conditions of less moisture and its more uneven distribution than are other crops; hence their extensive use. An understanding of how the different groups and varieties respond to the varying seasonal conditions is necessary to a further increase in their usefulness. To show this response, it is necessary to present climatic data much more completely than is usual in bulletins of this kind; hence the large space allotted to such data and their discussion in the present bulletin. It accounts also for the inclusion in the tables of more agronomic data than often is given in a presentation of the results of varietal experiments.

The Office of Cereal Investigations began its experiments with these crops in the Panhandle in 1904. These experiments were conducted for three years at Channing, Tex., on the X I T Ranch. In 1906, work was begun at Amarillo, Tex., where it is still in progress. Plat experiments were first developed on a large scale in 1908. This bulletin presents the results obtained in the 9-year period from 1908 to 1916, inclusive.

The experimental data include only the results of varietal experiments. A report of the experiments on spacing or rate of seeding and on date of seeding will be reserved for later publication. Among the agronomic data shown are the row space per plant and per stalk, the duration of the various stages of the growing period, the production of suckers, the percentage of erect heads in the milos, the height of the plants, and the yield in bushels per acre. For certain varieties and in certain years there are shown also the percentages, by weight, of heads in the total crop and of seed in the total crop and in the heads.

The data obtained have been used as a basis for the statements made in numerous popular and scientific publications,[1] in which, however, none of the detailed plat data were published. A brief summary of the experimental results was given by Ross and Leidigh in the bulletin cited.

THE PANHANDLE.

LOCATION.

The Panhandle strictly is that part of northwestern Texas which extends northward from the main body of the State. In common practice, however, this term is applied to a much larger portion of western Texas, including the so-called "Staked Plains." The word is here used in the broader sense. Figure 1 is a sketch map of this district. No definite eastern or southern boundary for the Panhandle has ever been fixed. The eastern boundary is generally held to be the escarpment locally known as the "cap rock," which roughly approximates the line of the 2,000-foot contour. The results given herein are applicable to all this district, including small portions of adjacent New Mexico and Oklahoma.

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[1] Ball, C. R. Three much-misrepresented sorghums. U. S. Dept. Agr., Bur. Plant Indus. Cir. 50, 14 p., 2 fig. 1910.

——— Better grain-sorghum crops. U. S. Dept. Agr., Farmers' Bul. 448, 36 p., 13 fig. 1911.

——— The importance and improvement of the grain sorghums. U. S. Dept. Agr., Bur. Plant Indus. Bul. 203, 45 p., 13 fig. 1911.

——— The kaoliangs: A new group of grain sorghums. U. S. Dept. Agr., Bur. Plant Indus. Bul. 253, 64 p., 15 fig., 1 pl. 1913.

——— The grain sorghums: Immigrant crops that have made good. U. S. Dept. Agr. Yearbook for 1913, p. 221–238, fig. 5–12, pl. 29–35. 1914.

——— and Leidigh, A. H. Milo as a dry-land grain crop. U. S. Dept. Agr., Farmers' Bul. 322, 23 p., 9 fig. 1908.

——— and Rothgeb, B. E. Kafir as a grain crop. U. S. Dept. Agr., Farmers' Bul. 552, 19 p., 8 fig. 1913.

Ross, J. F. Cereal crops in the Panhandle of Texas. U. S. Dept. Agr., Farmers' Bul. 738, 16 p., 5 fig. 1916.

——— and Leidigh, A. H. Cereal experiments in the Texas Panhandle. U. S. Dept. Agr., Bur. Plant Indus. Bul. 283, 79 p., 13 fig. 1913.

Rothgeb, B. E. Shallu, or "Egyptian wheat": A late-maturing variety of sorghum. U. S. Dept. Agr., Farmers' Bul. 827, 8 p., 2 fig. 1917.

Vinall, H. N., and Ball, C. R. Feterita, a new variety of sorghum. *In* U. S. Dept. Agr., Bur. Plant Indus. Cir. 122, p. 25–32. 1913.

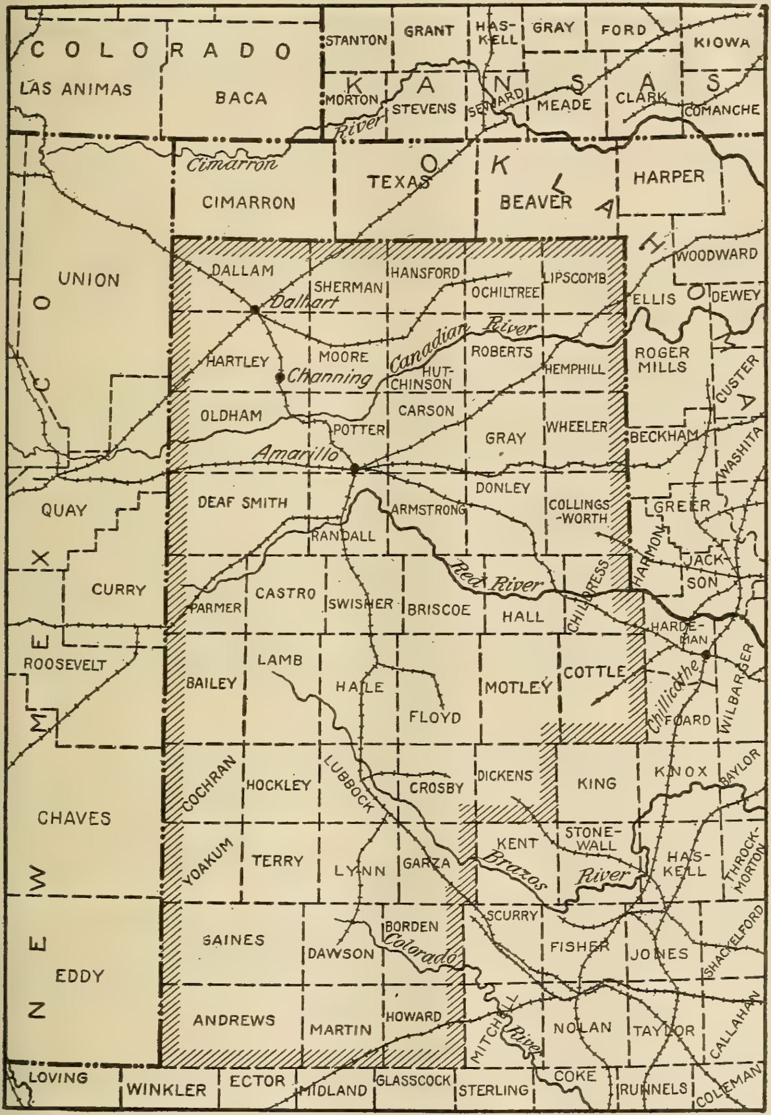

FIG. 1.—Sketch map of the Panhandle section of Texas and the surrounding country. The Panhandle section as discussed in this bulletin is indicated by the shaded boundary.

ALTITUDE AND DRAINAGE.

Most of this district is a high and nearly level table-land with an average altitude of about 4,000 feet and with a rather uniform slope to the east and southeast. The highest elevation reached is about 4,800 feet in the extreme northwest, while the southeastern border has an altitude of only 1,500 to 2,000 feet. The eastern rim of the high plains is a rough, broken strip where the cap rock is being worn through and erosion is rather rapid. Still farther east, below the cap rock, the surface is rolling.

Drainage is eastward through the tributaries of several rivers, among them being, from north to south, the Cimarron, Canadian, Red, Pease, Brazos, and Colorado. In the high plains, above the cap rock, these streams tend to form canyons, the most notable being that of the Red River from Canyon, in Randall County, eastward for about 60 miles.

SOIL.

The soils vary in type from a light sand in some parts to a heavy clay or adobe in others, with clay soils predominating. The sandy soil is covered with bunch grasses, while the heavier soils are covered with a turf of buffalo, blue grama, and curly mesquite grasses. These soils are all quite fertile, to judge from their power to produce crops when there is sufficient moisture. They are, however, deficient in humus because of the scanty growth of the native vegetation. The absence of sufficient humus in the soil lessens its capacity to absorb and retain the moisture which falls upon it. It also leaves the soil in a condition to become puddled by heavy rains and to bake readily thereafter.

CLIMATIC CONDITIONS.

The United States Weather Bureau has maintained a weather station at Amarillo, Tex., in the heart of the Panhandle, since 1892. There are disconnected records from two Army posts covering an earlier period. The data herein considered are all from Amarillo or from the near-by cereal field station.

The principal climatic features which influence crop production in the Panhandle are (1) a limited annual precipitation of irregular seasonal distribution, with a great loss of water due to run-off during torrential summer storms; (2) a relatively low atmospheric humidity; (3) a high average wind velocity; (4) a wide daily range of temperature, or hot summer days followed by cool nights; and (5) a very high rate of evaporation.

Precipitation.

Moisture is the limiting factor in crop production in most of the Panhandle. Precipitation is the primary and most important factor in the moisture problem.

MONTHLY AND ANNUAL PRECIPITATION.

In Table I are shown the monthly, the annual, and the mean annual precipitation, in inches, at Amarillo, Tex., during the 25-year period from 1892 to 1916, inclusive. The monthly precipitation and the departure from the normal will be found in Table IV. The mean annual precipitation at Amarillo during this 25-year period is seen to be 21 inches, more than three-fourths of which falls during the growing season for grain sorghums, the six months from April to September, inclusive.

TABLE I.—*Monthly and annual precipitation at Amarillo, Tex., during the 25-year period from 1892 to 1916, inclusive.*

[Data (in inches) furnished by the observer of the United States Weather Bureau at Amarillo, Tex. T. = trace.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.	Mean annual.
1892	0.42	0.57	2.10	0.21	2.70	1.49	1.85	1.93	0.24	2.85	0.16	1.08	15.60	......
1893	.09	2.03	T.	.16	2.19	2.03	2.05	2.67	5.27	.03	.28	.43	17.23	16.42
1894	.02	1.15	.05	.85	1.30	3.59	1.82	3.41	2.41	.39	......	.82	15.81	16.21
1895	1.60	1.92	.16	1.31	1.78	6.84	2.88	3.87	.57	2.26	.81	.79	24.79	18.36
1896	.76	.41	.21	1.95	2.20	2.31	7.04	.63	2.45	3.09	.35	2.88	24.28	19.54
1897	2.26	.65	.47	1.08	4.44	2.32	2.16	2.71	.73	1.63	.08	.63	19.16	19.48
1898	.86	.82	.35	.98	3.52	4.81	3.88	4.03	.48	.41	.34	2.06	22.55	19.91
1899	.29	.07	.17	.23	3.12	4.45	6.96	.51	6.09	1.15	3.24	1.11	27.39	20.85
1900	.59	.47	.48	5.47	4.53	1.94	3.21	.83	5.25	1.58	.08	.07	24.40	21.24
1901	.03	.48	.02	4.90	5.99	.82	1.56	3.03	2.19	3.26	2.00	.04	24.42	21.56
1902	.04	T.	.54	1.83	9.14	2.01	1.45	2.42	.95	1.74	2.24	.55	23.11	21.70
1903	.12	2.93	.26	.90	1.79	2.83	3.38	4.67	.82	2.58	......	T.	20.28	21.58
1904	.16	.08	T.	.63	2.88	5.53	2.48	4.69	3.55	.44	.20	.69	21.33	21.56
1905	1.00	1.52	2.62	4.52	6.16	2.19	3.76	.63	3.08	.30	5.09	1.45	32.32	22.33
1906	.41	.51	.64	3.23	1.18	2.07	2.90	6.76	1.96	2.49	2.58	.19	24.92	22.50
1907	1.11	.24	.02	1.25	.99	1.97	1.49	6.20	.91	1.79	.66	1.46	18.09	22.22
1908	.26	.72	T.	1.90	3.55	1.73	5.40	2.75	1.83	.40	.51	......	19.05	22.04
1909	.07	.28	1.28	.50	1.08	4.72	3.63	.87	2.19	1.18	3.25	.54	19.59	21.90
1910	.05	.17	.34	.59	2.99	.66	3.57	2.19	.05	.26	.28	T.	11.15	21.34
1911	.13	2.88	.50	2.76	5.88	.20	3.85	2.97	.83	.84	.94	.95	22.73	21.41
1912	T.	1.85	.78	.82	1.62	2.31	2.50	1.51	2.28	.33	T.	.33	14.33	21.07
1913	.11	.55	.59	1.76	1.41	2.32	1.80	.61	4.19	.81	1.98	2.84	18.97	20.98
1914	.06	.01	.15	.95	4.43	.84	3.07	2.97	1.07	4.46	T.	1.17	19.18	20.89
1915	.72	1.60	1.00	5.05	1.70	1.04	4.14	5.85	4.69	1.55	.18	.13	27.65	21.18
1916	.36	.02	.57	1.71	.89	2.18	.94	3.82	1.76	2.90	.40	.88	16.43	20.99
Average	.46	.88	.53	1.82	3.09	2.53	3.11	2.90	2.23	1.55	1.06	.84	20.99	......

A study of Table I shows, among other things, that there is a wide fluctuation in the annual precipitation, which comes mostly in the form of rain. For example, in 1910 it was 11.1 inches, while in 1905 it was 32.3 inches, or almost three times as much. The next lowest record is 14.3 inches, in 1912, and the next highest 27.7 inches, in 1915.

Interesting figures in the table are those which apparently show periodical recurrence in precipitation. The records begin only in 1892. In the first 3 years the annual precipitation was low, the highest being only 17.2 inches. The mean for these 3 years is only 16.2 inches. Then follows a period of 12 years, 1895 to 1906, inclusive, in which the annual precipitation is high. In this period it drops below 20 inches but once, in 1897. On the other hand, it once exceeds 30 inches, in 1905, when the total precipitation was 32.3 inches. The mean annual precipitation in this 12-year period is 24.1 inches. The third and final period covers the 10 years from 1907 to 1916, inclusive. Here, again, the annual precipitation has been comparatively low. Only twice in these years has it exceeded 20 inches. The lowest record is 11.2 inches, in 1910, and the highest 27.7 inches, in 1915. The mean annual precipitation in the period is 18.7 inches. Of course, these records cover far too short a period in which to prove the occurrence of cycles in rainfall or other climatic factors.

DISTRIBUTION OF DAILY AND MONTHLY RAINFALL.

The figures representing the total annual or seasonal precipitation may easily be misleading, especially to a person who is not familiar with this section of the country. This is due to the irregular distribution of summer rainfall in time and extent, to the varying quantities deposited by different showers, and to the manner in which it falls. The nature and distribution of the rainfall will be better understood by a study of the data in Table II, containing the records of daily precipitation, with monthly totals, throughout the 10 years from 1907 to 1916, inclusive. The monthly precipitation and its departure from the normal are summarized in Table IV.

TABLE II.—*Daily and monthly precipitation at Amarillo, Tex., during the 10-year period from 1907 to 1916, inclusive.*

[Data (in inches) furnished by the observer of the United States Weather Bureau at Amarillo, Tex. T. = trace.]

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1907:												
1							0.70	0.03				
2				T.	T.		.03	1.42		0.02		
3		T.				0.32		.14	0.21	.65		
4				0.29				.19				
5				T.								
6					0.02	.05						
7					T.					.05		
8	0.85				T.							
9	T.		T.		.34				.68			
10							.41				0.01	
11											.02	
12	.05					T.	.01					
13					T.							
14					.02	T.	T.					
15							T.					
16	.03						T.					
17	T.					1.27					.01	
18	.05				T.	.09				T.	.05	
19	.01			.04				.41	.02	.03	.57	
20				.28		.24		.07				
21				.48		T.		1.47		.25		
22				.04	.03			2.30				
23					.05							
24	.02					T.				.54		
25	.03						T.			.02		
26	.03						.26					
27		0.24	T.				.04					
28			0.02		.14		.04			.02		
29				.11	.17							
30	.04			.01	.19			.01	T.			
31					.03			.16		.14		
Total	1.11	.24	.02	1.25	.99	1.97	1.49	6.20	.91	1.79	.66	1.46

TABLE II.—*Daily and monthly precipitation at Amarillo, Tex., during the 10-year period from 1907 to 1916, inclusive*—Continued.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1908:												
1							1.07		0.74			
2	0.02							0.82	.05			
3	.20	0.01										
4		T.		0.01						0.15		
5	T.											
6						0.42	.01					
7				T.		.34	.18					
8			T.									
9				.15		T.						
10		.01										
11		.10		T.				T.			0.01	
12							T.				.04	
13		.12					.10	.77			T.	
14		.48						T.	.23			
15	.04			.62								
16				.09	0.46				.15			
17							.54	T.				
18							.02			T.		
19				1.03			.36			.15		
20								.11				
21								T.				
22					1.81			.48	T.	.10		
23		T.			1.05		T.					
24					T.	.35						
25									.32			
26								.25	.18			
27						T.	1.13	.32	.16		.09	
28						.58					.36	
29			T.	T.			.04				.01	
30			T.		.19	T.	.60					
31							1.35	T.				
Total	.26	.72	T.	1.90	3.55	1.73	5.40	2.75	1.83	.40	.51	0
1909:												
1	T.					T.	1.18					
2	.01					.10						
3							.02	.10				0.01
4		.02					T.	.06	.47			.12
5		.02						.04	.20			
6						T.	.67		T.			T.
7						.20		.32	1.49			
8			0.07	.07	.04	T.	.82	T.		.04		T.
9							.20	.34				
10	T.					.20						
11	.06		.44			.34						
12			.20	T.		.08			.03		.99	
13		T.				.88		T.	T.		.12	
14		T.				.18		T.			T.	T.
15						.01	.01	.01			.24	
16					T.	T.						
17										.92		.36
18		.24							T.	.21		.05
19			T.		.27		T.	T.		.01		T.
20		T.		.18	.60	1.08		T.				
21				.06		.34						
22				.11	.05	T.						T.
23		T.		T.	.03							
24			T.		.03	.31						
25						.65	.10					
26						.25	.63					
27					.05						.57	
28											.98	
29											.35	
30			.03	.30	.01	.01						
31			.54									
Total	.07	.28	1.28	.50	1.08	4.72	3.63	.87	2.19	1.18	3.25	.54
1910:												
1						T.	.21					
2		T.					.01		T.			
3	T.	T.			.57			.67				
4	.03			.10	.31							
5					.02	.01	.05	.02			.27	
6						.02	.07	.18				
7					T.							
8							.32					
9				.22			2.05	.64				
10							.02	.18				

TABLE II.—*Daily and monthly precipitation at Amarillo, Tex., during the 10-year period from 1907 to 1916, inclusive*—Continued.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1910—Contd.												
11	0.01								T.	0.02		
12	.01			T.				T.				
13				0.26	0.26	0.02						
14	T.			T.	.03				T.		0.01	T.
15			0.06	.01	.77	T.		T.				
16		0.17	.15					0.19				
17			T.		T.			.01				
18					.17		T.	T.				
19			T.							.06		
20										.18		T.
21					.60							
22					.05	.01			T.			
23		T.			.01							
24						T.		.26	0.05			
25			T.		T.	.07		.02				
26		T.				.25						
27					.20							
28			.13			.28						T.
29												
30					T.							
31							0.84	.02				T.
Total	.05	.07	.34	.59	2.99	.66	3.57	2.19	.05	.26	.28	T.
1911:												
1	.05							.20			.08	
2				T.			.01			.13	.33	
3				T.			T.				T.	
4		T.		.01	T.		.01			T.	T.	
5									T.	T.	.12	
6						T.	.32					
7							.04		T.			
8												
9						.11	.03		.13			0.01
10		.15		T.								
11							.06					
12					T.		.32					
13					.40		.42					.02
14					.15		T.					T.
15	T.				.01				.41			
16		.46					.03					
17	.07	1.61				.08	.50					
18		.22							T.			.04
19		.15					.68		T.			.76
20			.40		.04		.47		.01	.07		.07
21		T.	.10	.04			.49	.07		T.		
22							.12	.66				
23	.01			2.61				2.02				
24				.07								
25				.02		T.						.02
26				.01	.61					.19	.06	T.
27		.03				.01	.16	T.		.17	.35	
28	T.	.26			1.64		.03	.02		.14		
29					2.90		.14			.14		T.
30					.13				.28			.03
31							.02					
Total	.13	2.88	.50	2.76	5.88	.20	3.85	2.97	.83	.84	.94	.95
1912:												
1				.03			.01			.07		
2							T.					
3	T.	T.					.11	.36	T.			
4							T.	.43	.11			
5	T.			.21					.09			
6						.03		.35				.07
7					.17			T.		.01		
8				.08	.06	.18		T.				
9					.46	.19						
10			.15		T.			.32	.24			
11	T.			T.		1.48			1.17			
12					.21	T.			.11			
13		.14			.04				.40			
14					.28				.03			
15		.07		.11					T.			
16				T.			.02		.12			
17	T.			.04		.02	.47		.01			
18				.15								
19						.01				T.		
20		.14	T.				.22	.05				
21												
22						.03						.26

TABLE II.—*Daily and monthly precipitation at Amarillo, Tex., during the 10-year period from 1907 to 1916, inclusive*—Continued.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1912—Contd.												
23			0.26			0.29						
24				0.18			T.					
25		1.50			0.40							
26							0.34	T.			T.	
27				.02								
28							.28					
29	T.											
30						.08	.94			0.25		
31			.37		T.		.11				T.	
Total	T.	1.85	.78	.82	1.62	2.31	2.50	1.51	2.28	.33	T.	0.33
1913:												
1	T.						.01					.05
2		.12			.08				T.			.27
3		.06	T.		.01	.01				T.	0.45	.21
4					.67	.44			T.		.27	1.10
5	0.02					T.						.14
6	.03			T.		.05			T.			
7	.06	.22		T.		.32			T.			
8				.03	.11	.09		.17	.35			
9			T.	T.	.49	T.						
10		.03	.02			.06		.17	.77			
11			.03		T.	.03		.09	.68			
12			T.			.76		T.				
13			T.		T.							
14			.06									
15			T.							.10	T.	T.
16									.39	.15	.01	.34
17								T.		.26		
18						.11				.23	T.	
19				T.	T.	.06						T.
20		.06	T.	T.		.16	.05					
21				.13		.19		.05				.67
22		T.		1.14						T.		.06
23				.46			.15		.18			
24		T.					T.		.03			
25			.30		T.		.82	T.	.60		.25	
26			.18				.01	.08	.28	.07		
27		.03			.01		.03		.90			T.
28		.03				.03	.73	.02	.01			
29					.04	T.		.03			.95	
30				T.		.01					.05	
31												
Total	.11	.55	.59	1.76	1.41	2.32	1.80	.61	4.19	.81	1.98	2.84
1914:												
1					.96		.57					
2				.04		.06	.04	.62				
3	T.			.17	T.							
4							.22	.67				
5		T.						.11				
6				.43			.63		.30			
7				.17		.10	.07					
8												
9								.58				
10				.10				.41	.31			
11			T.	.01					.29	.09		
12								T.	.15			
13												
14					.04	.05				T.		
15					.48	.01			.01			
16					.81							
17					.09		.21					
18				.11	.47							
19					.07		.11					
20			.01		T.	.43						.43
21					T.				T.	.15		
22				.01					.04	2.28		
23										1.46		
24												.44
25							.02					
26				.06	T.							
27		.01			.22		.03					
28				T.	.47							
29			.01	.03	.02			.13				
30				.19	T.	T.						
31					.20							
Total	T.	.01	.02	1.27	3.83	.65	1.90	2.52	1.10	3.98	0	.87

TABLE II.—*Daily and monthly precipitation at Amarillo, Tex., during the 10-year period from 1907 to 1916, inclusive*—Continued.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1915:												
1						0.22	0.02	0.02				
2			0.20	T.		.03	.01					
3			.10				.06					
4			.25			.23	.33					
5					T.	T.	T.		T.			
6			T.	0.25	0.08	T.			T.			0.05
7				.40		.01		T.				
8			.04	.25			T.	.73				
9			.17	.01			.01	.32				
10											T.	
11								T.		0.21		
12							.01			.12		
13							.79					
14				.05				2.89		1.13		
15	T.		T.	.63			.61	.36	0.11	.09		
16	0.29			.30	.39		1.33	.20	.02			
17				1.34	.44			T.	.34		0.18	
18		T.		T.	.01		T.		.04			
19			T.	.03	T.		.21		.11			
20		0.83			.19		.54		T.			
21		T.	T.	.09				.27				
22	.03	T.		.07		T.			.14			
23	.01							.31	.03			
24				.73			.12	.20	.22			T.
25	T.			.28		.40	.02		3.05		T.	
26	T.	.58	T.		.23				.01			
27		.19			.21	.06		T.				.02
28						.09		.55				
29	.01			.55	.11	T.	.08		.05			
30	.12			.07	.04	T.	T.		.57			
31	.26		.24									.06
Total	.72	1.60	1.00	5.05	1.70	1.04	4.14	5.85	4.69	1.55	.18	.13
1916:												
1		.02		T.						T.		
2												
3												
4	T.			.22		1.38						
5						.15						
6				.06		.04			T.			
7				T.				T.				.21
8								.03	.06		.03	.05
9					T.							
10	T.		T.						.51	.70		.04
11	.07				T.		T.		.01	.02	T.	
12		T.		.04		T.	.01		.01	.82	T.	
13				.16		T.		.28		.02	.03	
14			T.	.97		.03		.01		1.07		T.
15					.01	.35						
16	.05					.12		.04		T.		
17	.12				.88			.14				T.
18							.02		.17			
19					T.		.19	.27	.01			
20	.11			.12			T.	.99				.16
21								1.49			.34	.11
22						.11		.41				
23			.17					T.	.70			
24									.29	.04		
25	T.			.02								
26	T.			.12								
27	T.						T.					
28	T.	T.					T.			.23		
29	.01						.72					
30	T.			T.			T.	.16				.20
31			.40					T.				.11
Total	.36	.02	.57	1.71	.89	2.18	.94	3.82	1.76	2.90	.40	.88

In most of the years during which these experiments have been continued the annual precipitation has been sufficient in quantity for the production of good crops of grain sorghums. In several of these years, however, good crops have not been obtained. The varying degrees of failure have been correlated in some measure with unfavorable distribution of the large and important seasonal rainfall. Figure 2 shows in graphic form the annual and seasonal rainfall (April to September, inclusive) during the 10-year period from 1907 to 1916, inclusive.

Unfavorable distribution may occur in various ways. Much or most of the seasonal rainfall may come near the beginning or toward the end of the growing season. While the total quantity may have been about normal, protracted drought may have occurred during some part of the year. The occurrence of spring droughts in 1907 and 1909 is shown in Table II. In these years no effective rains fell until the middle of June. The same conditions prevailed to a lesser extent in 1913; while the autumn also was unusually dry.

In the second case, a considerable rainfall may come all at the beginning of one month and again at the end of the following month. Several weeks of drought may have intervened between two rainy periods, although the total precipitation in each of the two months was about normal. A study of the daily precipitation record of the years 1911, 1912, and 1913 in Table II will illustrate this condition. In 1911 there was no effective rain between July 21 and August 22, though the rainfall in both months was good. In 1912 there was no effective rainfall between June 11 and July 17, and in 1913 from June 12 to July 25, although the total precipitation in each of these months except the last was satisfactory in quantity.

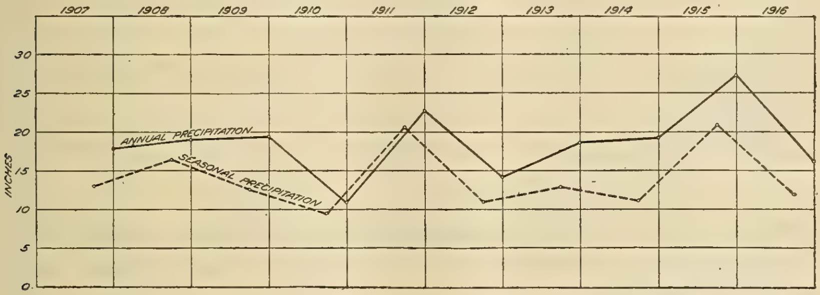

FIG. 2.—Diagram showing the seasonal (April to September) and annual precipitation, in inches, at Amarillo, Tex., during the 10-year period from 1907 to 1916, inclusive.

A third condition occurs in which a rainfall may be evenly distributed in point of time and about normal in quantity and yet be deficient for crop production. This is when it occurs in the form of light showers which do not penetrate the soil and are soon evaporated. Several showers of about a quarter inch each may add no water to the soil if followed by drying winds and bright sunshine, which cause rapid evaporation. Such showers are then of little or no value to the growing crop. The months of June, July, and August, 1912, and June, 1913, are examples of this condition, as may be seen in Table II.

LOCAL VARIATION IN PRECIPITATION.

Much of the summer rainfall is derived from storms which are very local in extent. In a single storm period a series of heavy showers may occur at about the same time in the same district but covering different localities and leaving intervening stretches almost unwatered.

The variation in the rainfall at two near-by points is illustrated in Table III. This table compares the rainfall measured at the United States Weather Bureau observatory in the town of Amarillo with that recorded at the Amarillo Cereal Field Station during seven summer months in the years 1909 and 1914. The distance between the two points of observation is about 2½ miles.

TABLE III.—*Comparison of the rainfall, in inches, at the United States Weather Bureau observatory and at the Amarillo Cereal Field Station during the seven months from March to September, inclusive, in 1909 and 1914.*

Station.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Total.
Season of 1909:								
United States Weather Bureau	1.28	0.50	1.08	4.72	3.63	0.87	2.19	14.27
Cereal field station	1.08	.27	1.13	5.90	2.19	1.39	1.90	13.86
Season of 1914:								
United States Weather Bureau	.15	.95	4.43	.84	3.07	2.97	1.07	13.48
Cereal field station	.02	1.27	3.83	.65	1.90	2.52	1.10	11.29

These local rains frequently last but a short time, but are of a torrential nature. This often results in a loss of much water by run-off. Such beating rains also puddle the surface soil and cause much damage in that way.

HUMIDITY.

The atmospheric humidity is low, on the average. This no doubt plays an important part in influencing transpiration from growing crops.

WIND.

Monthly data on wind are shown with other climatic data in Table IV. The average hourly wind velocity in the 10 years from 1907 to 1916, inclusive, is 11.8 miles. During the 4-year period from 1907 to 1910, inclusive, there was an average of 14 days in each year in which a wind velocity of over 40 miles an hour was recorded. The maximum, 63 miles, occurred on March 24, 1909. During the 6-year period from 1911 to 1916, inclusive, the data show merely the maximum hourly velocity recorded during the month and no longer the number of days having high wind velocities. The maximum, 46 miles an hour, occurred in February and April, 1911, and in April, 1915. Such high winds often cause great damage to the crops either by covering up the young plants, by cutting them off by moving particles of soil, or by blowing down the crop when it is almost or quite mature.

TABLE IV.—*Monthly climatic data, covering temperature, precipitation, aspect of sky, and wind movement, recorded at the observatory of the United States Weather Bureau, Amarillo, Tex., during the 10-year period from 1907 to 1916, inclusive.*

Year and month.	Temperature (° F.).							Precipitation (inches).			Aspect of sky (days).			Wind.		
	Mean.	Departure from the normal.	Maximum.		Minimum.		Greatest daily range.	Total.	Departure from the normal.	Snowfall unmelted.	Clear.	Partly cloudy.	Cloudy.	Prevailing direction.	Movement.	Velocity of 40 or more miles per hour.[1]
			Reading.	Date.	Reading.	Date.										
1907:															*Miles.*	*Days*
Jan.....	52.4	+10.5	74	5	15	25	46	1.11	+0.42	0.9	15	12	4	S.	9,467	0
Feb.....	44.2	+ 8.6	74	8	7	3	42	.24	− .63	.6	21	4	3	S.	7,789	1
Mar.....	56.8	+11.8	96	19	20	1	46	.02	− .18	0	25	4	2	S.	10,039	2
Apr.....	52.6	− 2.0	90	10	23	30	55	1.25	− .45	8.3	18	8	4	S.	10,313	2
May.....	59.0	− 5.3	90	17	26	4	40	.99	−2.19	0	20	8	3	NW.	10,260	1
June....	71.6	− .4	104	29	44	1	44	1.97	−1.02	0	21	7	2	S.	9,585	1
July.....	76.0	− .1	99	24	55	1	36	1.49	−1.68	0	21	9	1	S.	9,606	2
Aug.....	76.3	+ 1.7	97	15	58	31	35	6.20	+3.39	0	16	11	4	S.	9,019	1
Sept.....	70.8	+ 3.1	91	7	42	28	38	.91	−1.45	0	17	13	0	S.	8,503	1
Oct.....	57.6	+ 1.5	86	2	35	8	57	1.79	+ .80	0	10	12	9	S.	8,196	1
Nov.....	43.3	− .5	74	6	16	12	38	.66	− .50	4.0	14	9	7	S.	6,725	0
Dec.....	38.3	....	71	1	12	18	37	1.46	....	1.4	15	11	5	S.	9,773	1
1908:																
Jan.....	38.8	+ 4.9	70	9	7	16	44	.26	− .35	.4	18	10	3	S.	10,222	2
Feb.....	40.4	+ 3.2	77	28	4	1	43	.72	− .20	6.0	17	10	2	NW.	9,318	4
Mar.....	52.2	+ 7.2	86	17	20	9	48	T.	− .65	T.	23	6	2	S.	9,363	2
Apr.....	55.7	+ 1.1	80	14	29	2	38	1.90	+ .18	0	20	9	1	S.	9,093	2
May.....	63.5	− .8	91	19	34	7	43	3.55	− .12	0	28	1	2	SW.	11,050	1
June....	73.3	+ 1.3	96	21	52	2	36	1.73	−1.26	0	27	3	0	S.	11,011	2
July.....	72.8	− 3.3	96	11	55	7	31	5.40	+2.23	0	16	13	2	S.	8,460	0
Aug.....	74.5	− .1	97	10	58	8	33	2.75	− .60	0	22	9	0	S.	7,891	0
Sept....	67.6	− .1	97	6	36	28	35	1.83	− .53	0	22	7	1	S.	7,259	0
Oct.....	56.7	+ .6	86	15	28	27	43	.40	−1.31	1.0	27	4	0	S.	9,812	2
Nov.....	45.3	+ 1.5	78	17	11	14	46	.51	− .65	1.3	24	2	4	NW.	7,067	1
Dec.....	41.2	+ 4.8	72	16	18	19	41	0	− .83	0	25	4	2	S.	8,337	0
1909:																
Jan.....	41.0	+ 7.1	80	8	3	12	63	.70	− .53	.6	26	4	1	S.	10,167	2
Feb.....	41.6	+ 4.4	72	12	3	14	55	.28	− .60	T.	22	6	0	S.	10,264	4
Mar.....	44.9	− .1	80	22	14	12	45	1.28	+ .63	12.5	21	8	2	NW.	9,542	2
Apr.....	54.0	− 1.6	89	17	26	1	45	.50	−1.26	1.6	24	5	1	S.	10,794	4
May....	62.5	− 1.8	93	28	27	1	45	1.08	−2.59	0	21	9	1	S.	9,663	4
June....	73.5	+ 1.5	99	6	52	3	37	4.72	+1.73	0	13	15	2	S.	9,003	2
July....	77.9	+ 1.8	96	11	62	1	30	3.63	+ .46	0	15	16	0	S.	8,270	0
Aug.....	78.0	+ 3.4	102	17	57	25	35	.87	−1.94	0	12	17	2	S.	7,599	0
Sept....	69.4	+ 1.7	95	2	45	23	40	2.19	− .17	0	19	11	1	S.	7,906	0
Oct.....	57 9	+ 1.8	88	16	29	12	44	1.18	− .53	0	20	7	4	S.	9,619	2
Nov.....	50.4	+ 6.6	85	6	26	16	45	3.25	+2.09	6.2	16	7	7	S.	8,456	0
Dec.....	31.0	− 5.4	75	31	3	19	40	.54	− .29	5.3	15	10	6	N.	7,878	0
1910:																
Jan.....	39.6	+ 5.7	76	1	9	5	40	.05	− .55	.3	10	15	6	SW.	8,483	0
Feb.....	35.6	− 1.6	76	14	− 4	17	44	.17	− .71	1.7	15	9	4	N.	8,981	0
Mar.....	56.5	+11.0	87	25	31	10	48	.34	− .31	0	24	7	0	S.	9,183	4
Apr.....	58.5	+ 3.9	94	29	30	5	43	.59	−1.13	1.1	22	5	3	NW.	9,578	1
May.....	61.6	− 2.7	95	10	38	3	39	2.99	− .68	0	10	15	6	N.	9,294	0
June....	75.9	+ 3.9	103	2	50	11	40	.66	−2.33	0	15	15	0	S.	9,629	0
July....	79.5	+ 3.4	100	8	58	1	37	3.57	+ .40	0	15	16	0	S.	8,330	1
Aug.....	76.3	+ 1.7	99	28	49	26	36	2.19	− .62	0	18	13	0	S.	7,691	1
Sept....	73.8	+ 6.1	101	11	46	27	44	.05	−2.31	0	16	14	0	S.	8,694	0
Oct.....	60.4	+ 4.3	94	4	28	28	45	.26	−1.45	1.6	23	7	1	S.	8,306	0
Nov.....	49.0	+ 5.0	82	12	24	30	39	.28	− .88	2.7	23	6	1	S.	7,642	0
Dec.....	39.8	+ 3.4	73	9	16	30	42	T.	− .83	T.	15	12	4	S.	8,155	0
1911:																
Jan.....	45.6	+11.7	82	31	− 6	3	44	.13	− .47	.5	14	16	1	SW.	9,309	35
Feb.....	38.6	+ 1.4	77	1	7	22	37	2.88	+2.00	7.3	18	5	5	SE.	8,370	46
Mar.....	51.4	+ 6.4	83	9	21	1	42	.50	− .15	0	25	6	0	S.	9,272	43
Apr.....	56.8	+ 2.2	87	22	35	7	42	2.76	+1.04	0	16	11	3	S.	9,732	46
May....	65.6	+ 1.3	92	9	36	1	39	5.88	+2.21	0	15	14	2	SE.	11,140	36
June....	77.0	+ 5.0	105	25	59	4	35	.20	−2.79	0	21	9	0	SE.	8,544	39
July....	75.4	− .7	96	5	54	25	29	3.85	+ .68	0	7	19	5	SE.	7,160	33
Aug.....	75.8	+ 1.2	102	6	54	28	38	2.97	+ .16	0	18	11	2	SE.	7,711	30
Sept....	75.2	+ 7.5	95	5	54	19	36	.83	−1.53	0	16	13	1	S.	7,076	33
Oct.....	57.1	+ 1.0	91	1	26	28	45	.84	− .87	3.1	18	8	5	S.	8,363	44
Nov.....	41.6	− 2.2	75	75	16	5	29	.94	− .22	8.2	10	7	3	SW.	9,651	54
Dec.....	30.1	− 6.3	63	4	0	31	33	.95	+ .12	9.0	18	8	5	SW.	6,792	31

[1] In 1911, maximum velocity (miles) recorded during the month.

TABLE IV.—*Monthly climatic data, covering temperature, precipitation, aspect of sky, and wind movement, recorded at the observatory of the United States Weather Bureau, Amarillo, Tex., during the 10-year period from 1907 to 1916, inclusive*—Continued.

Year and month.	Temperature (° F.).							Precipitation (inches).			Aspect of sky (days).			Wind.		
	Mean.	Departure from the normal.	Maximum.		Minimum.		Greatest daily range.	Total.	Departure from the normal.	Snowfall unmelted.	Clear.	Partly cloudy.	Cloudy.	Prevailing direction.	Movement.	Maximum velocity (miles).
			Reading.	Date.	Reading.	Date.										
1912:															*Miles.*	
Jan	31.2	− 2.7	75	26	−11	6	50	T.	−0.60	T.	18	13	0	N.	8,234	37
Feb	35.6	− 1.6	72	18	6	4	33	1.94	+1.06	16.3	17	8	4	NW.	7,910	44
Mar	39.2	− 5.8	81	19	13	20	57	.82	+ .17	3.5	14	10	7	N.	10,047	39
Apr	54.6	0	89	30	31	2	39	.72	−1.00	T.	20	9	1	SW.	10,030	45
May	66.6	+ 2.3	95	24	38	14	38	1.67	−2.00	0	21	8	2	SW.	9,077	40
June	70.4	− 1.6	95	30	41	18	39	1.90	−1.09	0	18	11	1	SW.	7,788	31
July	79.2	+ 3.1	99	30	60	16	33	1.88	−1.29	0	21	10	0	SW.	8,585	38
Aug	76.4	+ 1.8	97	26	55	9	32	2.28	− .53	0	21	9	1	SW.	8,416	40
Sept	64.6	− 3.1	92	2	36	26	35	2.28	− .08	0	15	13	2	SW.	8,573	40
Oct	58.2	+ 2.1	83	4	28	22	40	.39	−1.32	0.6	21	9	1	SW.	8,377	32
Nov	46.9	+ 3.1	78	10	13	27	42	.02	−1.14	0.2	23	6	1	SW.	8,917	42
Dec	33.6	− 2.8	66	14	9	24	40	1.80	+ .35	11.4	24	5	2	SW.	8,316	37
1913:																
Jan	35.0	+ 1.1	67	29	− 2	7	38	.11	− .49	1.1	21	10	0	SW.	10,427	38
Feb	31.6	− 5.7	71	18	8	8	43	.55	− .33	5.1	14	10	4	NE.	6,553	27
Mar	43.3	− 1.7	80	30	10	24	44	.59	− .06	5.4	22	9	0	SW.	10,973	44
Apr	56.2	+ 1.6	87	17	28	4	43	1.76	+ .04	1.4	26	3	1	SW.	10,022	39
May	68.2	+ 3.9	94	29	44	15	39	1.41	−2.26	0	26	4	1	S.	9,355	34
June	70.2	− 1.8	93	2	51	10	34	2.32	− .67	0	17	8	5	S.	8,476	32
July	78.7	+ 2.6	101	14	58	21	34	1.80	−1.37	0	26	5	0	S.	9,493	36
Aug	80.0	+ 5.4	99	9	61	2	33	.61	−2.20	0	27	4	0	S.	7,490	30
Sept	64.8	− 2.9	94	7	38	28	38	4.19	+1.83	0	18	6	6	S.	7,349	38
Oct	55.2	− .9	85	14	24	29	46	.81	− .90	.7	22	9	0	SW.	8,492	44
Nov	50.3	+ 6.5	79	19	32	8	39	1.98	+ .82	0	18	6	6	SW.	8,558	40
Dec	33.2	− 3.2	54	11	4	23	35	2.84	+2.01	12.1	17	7	7	N.	6,945	37
1914:																
Jan	45.4	+ 9.8	82	27	20	30	38	.06	− .5	.6	23	7	1	W.	7,446	42
Feb	38.2	+ 1.0	77	17	− 1	6	57	.10	− .8	.8	21	5	2	SW.	7,225	36
Mar	47.3	+ 2.3	82	15	14	20	47	.15	− .5	1.4	22	8	1	SW.	7,349	37
Apr	56.0	+ 1.4	88	21	20	8	41	.95	− .8	1.8	15	13	2	SW.	9,827	40
May	63.2	− 1.1	95	10	42	12	36	4.43	+ .8	0	15	13	3	S.	8,416	37
June	76.2	+ 4.2	99	26	57	17	33	.84	−2.2	0	24	6	0	SW.	10,429	40
July	77.8	+ 1.7	97	31	60	2	30	3.07	− .1	0	19	12	0	S.	6,023	40
Aug	75.6	+ 1.0	94	31	57	28	33	2.97	+ .2	0	19	11	1	S.	6,559	31
Sept	72.8	+ 5.1	98	6	49	28	33	1.07	−1.3	0	21	9	0	S.	7,938	40
Oct	58.0	+ 1.9	86	17	30	27	41	4.46	+2.8	0	14	9	8	S.	8,184	30
Nov	50.4	+ 6.6	76	14	23	17	40	T.	−1.2	0	26	4	0	SW.	6,069	28
Dec	30.4	− 6.0	62	18	10	21	36	1.17	+ .3	0	13	11	7	SW.	7,450	35
1915:																
Jan	34.0	+ 0.1	64	14	9	22	50	.72	+ .1	5.9	22	7	2	SW.	9,049	40
Feb	41.4	+ 4.2	76	10	20	28	45	1.60	+ .7	9.9	20	6	2	NW.	8,179	44
Mar	37.2	− 7.8	78	24	17	21	47	1.00	+ .4	8.1	14	12	5	N.	8,180	40
Apr	57.0	+ 2.4	88	28	29	1	38	5.05	+3.3	1.7	13	11	6	S.	7,997	46
May	61.5	− 2.8	92	25	30	7	41	1.70	−2.0	.....	21	5	5	S.	9,263	44
June	72.4	+ .4	103	20	42	7	37	1.04	−2.0	.....	19	8	3	S.	8,841	37
July	74.6	− 1.5	102	11	52	5	32	4.14	+1.0	.....	15	10	6	S.	8,893	44
Aug	71.4	− 3.2	95	4	48	30	32	5.85	+3.0	.....	20	8	3	S.	6,232	27
Sept	68.8	+ 1.1	94	10	47	30	33	4.69	+2.3	.....	23	4	3	S.	7,860	33
Oct	59.0	+ 2.9	83	2	37	26	36	1.55	− .2	.....	28	3	0	SW.	7,735	30
Nov	49.5	+ 5.7	82	5	20	14	45	.18	−1.0	1.8	28	0	2	SW.	9,070	42
Dec	40.2	+ 3.8	73	22	8	28	42	.13	− .7	.2	22	5	4	W.	8,275	40
1916:																
Jan	35.2	+ 1.3	74	9	1	13	55	.36	− .2	2.5	14	9	8	SW.	8,740	36
Feb	43.5	+ 6.3	81	11	9	1	54	.02	− .9	.2	24	5	0	NE.	7,022	32
Mar	53.7	+ 8.7	87	13	16	3	46	.57	− .1	4.0	28	2	1	NE.	9,687	40
Apr	52.9	− 1.7	87	11	26	8	47	1.71	.0	T.	18	7	5	NE.	9,123	42
May	67.0	+ 2.7	98	31	35	1	52	.89	−2.8	.....	26	4	1	SW.	9,585	37
June	74.6	+ 2.6	100	21	50	7	37	2.18	− .8	.....	17	11	2	S.	8,988	35
July	79.0	+ 2.9	100	3	61	7	32	.94	−2.2	.....	19	12	0	S.	6,856	25
Aug	76.6	+ 2.0	97	13	55	28	28	3.82	+1.0	.....	19	10	2	S.	7,652	39
Sept	67.8	+ .1	91	10	40	29	38	1.76	− .6	.....	18	12	0	S.	8,174	35
Oct	57.2	+ 1.1	89	3	27	19	39	2.90	+1.2	.....	19	4	8	S.	8,091	37
Nov	44.4	+ .6	85	4	5	14	42	.40	− .8	3.7	23	3	4	SW.	8,233	35
Dec	36.6	+ .2	73	4	0	21	40	.88	+ .05	6.3	21	7	0	SW.	9,145	40

TEMPERATURE.

The daily range in temperature is large, but not excessive. In general, the days in summer are warm to hot and the nights nearly always cool. Owing to the altitude (3,600 feet) the summer temperatures are not as high as might be expected from the southern location. On the other hand, winter temperatures are not as low as might be expected from the elevation.

The data on maximum, mean, and minimum temperatures and greatest daily range, by months, in the 10 years from 1907 to 1916, inclusive, are given in Table IV, which also contains data on precipitation, the aspect of the sky, and the movement of the wind. The lowest recorded temperature in the period covered by these records was −11° F. on January 6, 1912, and the highest 105° F. on June 25, 1911. The average date of the last spring frost is April 19 and that of the first fall frost October 30, leaving an average frost-free period of 194 days.

EVAPORATION.

The loss of moisture by evaporation in the Panhandle district is very great. The chief factors concerned are precipitation, wind, and temperature. The maximum evaporation naturally occurs, therefore, in periods of high temperatures and strong winds.

Table V contains a comparison of monthly precipitation and evaporation records made at the Amarillo Cereal Field Station[1] during the six months from March to September in the 10-year period from 1907 to 1916, inclusive. The evaporation measured is from the free water surface of a tank 8 feet in diameter. During this period, the evaporation was nearly four times as great as the precipitation during the same period. In 1909 a maximum of 0.69 of an inch was evaporated from this tank in 24 hours. These data show contributing causes for certain crop results in various years.

TABLE V.—*Monthly, seasonal, and 10-year monthly average precipitation and evaporation, in inches, at the Amarillo Cereal Field Station, during the six months from April to September, inclusive, for the 10-year period from 1907 to 1916, inclusive.*

Year.	April.		May.		June.		July.		August.		September.		Seasonal total.	
	Prec.	Evap.	Prec.	Evap.	Prec.	Evap.	Prec.	Evap.	Prec.	Evap.	Prec.	Evap.	Prec.	Evap.
1907....	1.3	6.4	1.1	8.1	2.2	9.6	1.5	10.7	6.2	9.4	1.0	7.9	13.3	52.1
1908....	1.9	7.3	3.4	9.3	1.7	10.4	4.6	8.1	3.4	8.6	1.5	6.8	16.5	50.5
1909....	.3	8.1	1.1	10.0	5.9	10.3	2.2	10.0	1.4	9.7	1.9	8.4	12.8	56.5
1910....	.5	8.5	2.6	8.0	1.5	12.0	2.6	12.2	2.5	8.8	.1	9.1	9.8	58.6
1911....	3.9	7.4	6.7	10.1	.4	11.5	5.9	7.5	2.5	8.9	1.3	7.3	20.7	52.7
1912....	.8	7.1	1.6	9.9	2.3	9.0	2.5	10.9	1.5	9.5	2.3	6.5	11.0	52.9
1913....	1.7	7.7	1.7	9.8	2.3	7.0	1.4	12.7	.5	10.3	5.6	5.9	13.2	53.4
1914....	1.3	6.7	3.8	6.7	.7	10.1	1.9	8.7	2.5	8.9	1.1	8.0	11.3	49.1
1915....	4.8	4.6	2.0	6.9	1.2	8.8	3.7	9.3	4.6	7.3	4.9	6.0	21.2	42.9
1916....	1.8	6.0	.9	10.3	2.7	10.7	1.2	11.7	3.4	10.2	2.2	7.7	12.2	56.6
Av.	1.8	7.0	2.5	8.9	2.1	9.9	2.8	10.2	2.9	9.2	2.2	7.4	14.2	52.5

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[1] The precipitation and evaporation data given in Table V were obtained at the Amarillo Cereal Field Station in cooperation with the Office of Biophysical Investigations and the Office of Dry-Land Agriculture of the Bureau of Plant Industry, U. S. Department of Agriculture.

RECENT AGRICULTURAL HISTORY.

Not more than 15 or 20 years ago the Panhandle was occupied by immense cattle ranches, used only for grazing purposes. The dense growth of short but nutritious grasses, chiefly buffalo grass and blue grama, furnished both winter and summer pasturage for countless numbers of beef cattle, which had no other feed from weaning time to marketing. Under this system from 15 to 40 acres of grazing land were required for each animal, depending on the nature of the grass cover, the character of the season, and the time of year.

Between 1890 and 1900, conditions in the stock-ranch industry became unsatisfactory and a change began. Overstocking the range had resulted in heavy losses during seasons of drought and during severe winters. A call for feeding crops suited to the Plains was coming from the ranchers. The demand for new, cheap lands for homes and crop production was increasing. The large ranches were being divided and portions sold for farms. This process is still going on throughout the range country.

Most of the settlers came from the more humid States of the Mississippi Valley area, where conditions are almost entirely different. Some of them brought the proceeds of high-priced lands and invested heavily; others came with only meager equipment and financial resources. Few of them had knowledge of the crop varieties or cropping methods most likely to be successful under the rigorous conditions prevailing on the high, dry plains. Most of them came expecting to grow the crops they had previously grown in more humid sections. An increasing demand for information came from new settlers who wanted suitable field crops and from ranchmen who wanted feeding crops.

THE CEREAL FIELD STATIONS.

In response to the increasing demand for information on dry-land crops, experimental work was begun by the Office of Cereal Investigations in 1903. Experiments were conducted for three years at Channing, Tex., on the X I T Ranch. In 1906 the work was transferred to Amarillo, Tex., where it has since been conducted. The work there was started on farm No. 1, situated 1 mile southwest of the town. In 1910 it was transferred to farm No. 2, which lies about 2 miles northeast of the town.

Amarillo is located in what is known on the Plains as "tight" land, a dark, clay loam, bearing a close turf of buffalo and grama grasses. The average rainfall is about 21 inches annually. This location is fairly representative of a considerable part of the Panhandle. The results obtained there are applicable to most of the Panhandle and to small adjacent portions of New Mexico and Oklahoma.

THE GRAIN SORGHUMS.

The grain sorghums consist of several very distinct groups of varieties. Different groups and varieties react differently to environmental conditions and therefore give different results. To understand these results it is necessary to know the characters by which the groups and varieties differ from each other. For this purpose a glance is taken first at the relationship of the grain sorghums to other sorghums. Keys to the groups of grain sorghums and brief descriptions of them are inserted next, and finally keys and descriptions covering the varieties in each group are presented.

CLASSIFICATION.[1]

The different sorghums grown in this country may be arranged in a general way in four agronomic divisions, as noted below.

(1) Grain sorghums, which include such well-known groups as kafir, durra and milo, and kaoliang, and also less commonly grown groups, such as shallu, etc.

(2) Sorgo, or forage sorghum, known also as sweet or saccharine sorghum, and improperly called "cane" or "sugar cane." This group includes such well-known varieties as Amber, Orange, and Sumac, as well as many others not so widely grown.

(3) Broom corn, which includes two rather distinct varieties, Standard and Dwarf.

(4) Hay sorghums, which include Johnson, Sudan, and Tunis grasses.

This bulletin is concerned only with the grain-producing sorghums. Figure 3 shows representative kernels of the most important varieties. The groups of the grain-sorghum section may be separated by the following key:

Spikelets broadly obovate, 4.5 to 6 mm. wide; seeds large, lenticular, flattened; panicle oval-ovate, short branched, compact............. DURRA-MILO.

Spikelets oval or narrowly obovate, 2 to 4 mm. wide; seeds midsized to small, ovoid, scarcely flattened.

  Stems stout, somewhat juicy; internodes short; leaves 12 to 15, broad, usually dark green.................................. KAFIR.

  Stems slender, dry; internodes longer; leaves 7 to 10, narrower and lighter green:

    Panicle compressed; glumes tightly appressed to the brown or white seeds... KAOLIANG.

    Panicle conical, loose; glumes spreading, exposing yellowish white seeds... SHALLU.

THE DURRA-MILO GROUP.

This group includes White and Brown durra, feterita, and White and Yellow milo. It is characterized by slender to midstout, dry, pithy stems, 0.8 to 2 meters tall, bearing 7 to 10 rather small leaves; panicles short, broad, ovate or oval, short branched, compact;

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[1] Classification studies in sorghums were made by the senior writer during the period of 1903 to 1906, inclusive. All obtainable domestic varieties and several hundred foreign varieties and strains were grown and studied. Acknowledgment of valued cooperation in this work is made to Director W. R. Dodson, of the Louisiana Experiment Station, to former Director A. M. Soule, of the Tennessee Agricultural Experiment Station, and to their assistants.

spikelets broadly obovate, 4.5 to 6 mm. wide; seeds broadly obovate to lenticular, 4 to 6 mm. in diameter, rather strongly flattened. The varieties of this group may be separated by the following key:

Glumes greenish white, densely pubescent, not transversely wrinkled; seeds much flattened.......... DURRA.
  Seeds white; lemmas awned.......... *White durra.*
  Seeds brown; lemmas not awned.......... *Brown durra.*
Glumes dark brown to black, thinly pubescent to glabrate, transversely wrinkled; seeds less flattened.
  Panicles narrowly oval, always erect; lemmas not awned; seeds chalky or bluish white.......... FETERITA.
  Panicles broadly oval or ovate, inclined to pendent; lemmas awned; seeds white or brown.......... MILO.
    Seeds white.......... *White milo*
    Seeds brown.
      Stems 1.2 to 2 meters high.......... *Milo.*
      Stems 0.8 to 1.3 meters high.......... *Dwarf milo.*

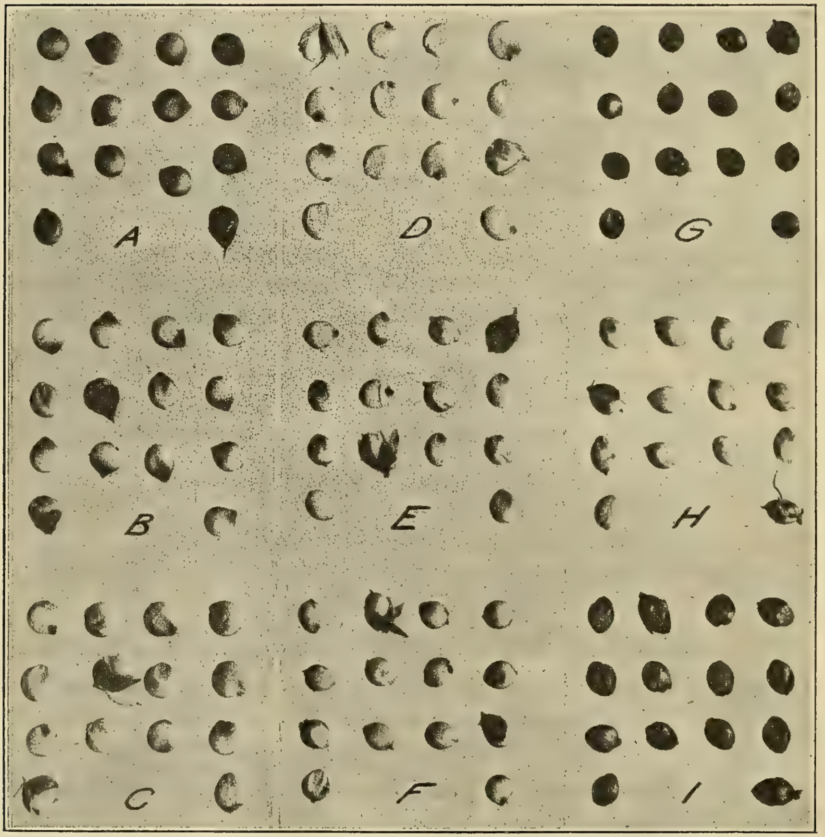

FIG. 3.—Seeds of nine varieties of grain sorghums, representing all the different groups: *A*, Milo; *B*, Alba milo; *C*, feterita; *D*, White durra; *E*, Durra-kafir hybrid (No. 198-7-3); *F*, Blackhull kafir; *G*, Red kafir; *H*, Mukden (white) kaoliang; *I*, Manchu (brown) kaoliang. (All natural size.)

THE KAFIR GROUP.

The kafir varieties are known by their stout, stocky, semijuicy stems, with short internodes and overlapping sheaths; leaves 11 to 16, broad; panicles erect, cylindrical, linear or narrowly to broadly oblong, heavy; spikelets obovate, 2.5 to 4 mm. wide; glumes much shorter than the seed; lemmas not awned.

The six varieties grown in this country may be distinguished by the following key:

Seeds white.
  Glumes black.
    Stalks 1.5 to 2.4 meters tall.
      Maturing late .... *Blackhull kafir.*
      Maturing midearly .... *Sunrise kafir.*
    Stalks 0.9 to 1.3 meters tall; maturing midearly . *Dawn (Dwarf Blackhull) kafir.*
  Glumes white .... *White kafir.*
Seeds pink.
  Glumes white .... *Pink kafir.*
Seeds red.
  Glumes black .... *Red kafir.*

THE KAOLIANG GROUP.

Stems slender, dry, pithy, 0.8 to 3 meters tall; leaves 8 to 11, small, narrow; panicle variable, mostly narrowly oval to oblong or clavate; spikelets obovate or oval, 2.5 to 3.3 mm. wide; lemmas always awned; seeds oval, often pointed, white or various shades of brown.

A large number of varieties of kaoliang have been grown in adaptation and classification studies. Most of these have been discarded, however, and it is not necessary to classify and separate them here.

Only one of these varieties has become established as a farm crop. This variety, the Manchu (Cereal Investigations Nos. 171 and 328), is now grown to some extent in South Dakota, and its use there seems to be increasing. It is a very early maturing variety, of medium height, 1.2 to 2.1 meters tall, with a narrowly oval, semicompact panicle 8 to 10 inches long, black glumes, and dark-brown seeds. The varietal name, Acro, has recently been given by the South Dakota Agricultural Experiment Station to a selection of the Manchu variety.

THE SHALLU GROUP.

Only one variety of the shallu group is found in the United States, and it apparently has little or no value for dry-land conditions. It grows from 1.5 to 2.4 meters tall, has slender, dry stems bearing 11 to 15 leaves of medium size, and large, loose, conical, pale-yellow panicles, 2 to 4 dm. long. The glumes are yellowish and at maturity spread wide apart and the edges become inrolled, completely exposing the small, oval, pale-buff seed.

EXPERIMENTAL CONDITIONS.

In order that the experimental results may be properly interpreted, descriptions of the methods of obtaining data and of the environing conditions prevailing in each season are given here.

METHODS EMPLOYED.

The size and arrangement of plats, the method and rate of seeding, the date when the crop was sown each year, the rotation of crops on the experimental area, and the methods of obtaining certain data are explained in the following paragraphs.

SIZE AND ARRANGEMENT OF PLATS.

The plats used in these experiments were 8 rods long by 2 rods wide, containing a tenth of an acre each. These plats were laid out in blocks of 10. Each block was bordered on all four sides by a road 19.2 feet wide. Each plat, therefore, had a road at each end, and the first and tenth plats in each group or block had a road on one side. A guard row usually is placed between the first and tenth plats and the adjacent roads.

In the experiments with small grains, definite alleys are left between plats, to prevent mixing and to facilitate the handling of the crop. Since the grain sorghums are sown in widely spaced rows no alleys were needed for these purposes, and usually none were left. The regular 42-inch space between rows served as an alley. In 1910, however, 5-foot alleys were left between the plats, thus giving the crop thereon the benefit of 9 inches of extra space on each side of the plat.

Each plat contained 10 rows, 132 feet long and 42 inches apart. Usually each variety occupied 10 rows, or a tenth of an acre. Sometimes, however, fewer than 10 rows were sown. In 1914 all varieties were sown on 5-row or twentieth-acre plats. In sowing the varieties the rows were made longer than 132 feet. When the plants were 15 to 20 inches (4 to 5 dm.) in height, the ends of the rows were trimmed to the proper limits.

METHOD AND RATE OF SEEDING.

A 1-row corn drill, fitted with special sorghum plates, was used for sowing the crop until 1910. Since then a 2-row corn drill, fitted in the same manner, has been used. The plates for sowing milo and durra contain 18 holes, each three-sixteenths of an inch in diameter. For kafir the plates have 16 holes, each five thirty-seconds of an inch in diameter, and for kaoliang 25 holes the same size as for kafir. The feed was run on high gear, which drops at intervals of 6.4, 7.2, and 4.6 inches, respectively, with plates bored as stated above.

It was the intention to have only one kernel dropped at a time, but in many cases two and sometimes three kernels were dropped because of the thickness of the plates and the varying size of the kernels.

DATES WHEN THE CROPS WERE SOWN.

In 1908 the Blackhull and Red Kafir varieties were sown on May 20 and 21; the other varieties between May 27 and 30. In 1909, seeding began on May 25 and ended on June 2, while in 1910 the beginning was on May 24 and the end on May 28. In 1911 the sowing occupied June 3 to 8, inclusive. In 1912 and 1913 these crops were sown during the eight days from May 20 to 27, inclusive, while in 1914 sowing was condensed into the 3-day period, May 23 to 25. In the last two years only two days have been required to sow all varieties. The sowing was done in 1915 on May 24 and 25 and in 1916 on May 25 and 26.

ROTATIONS ON THE EXPERIMENTAL AREA.

Owing to the lack of land and the shifting of the location from one farm to another in 1910 it was not possible to establish a regular rotation on the experimental plats. In 1908 most of the varieties were sown on sod land which had been broken during the previous fall and winter. In 1909 the varieties were scattered over the farm on various blocks which had been cropped to different small grains the year before.

In 1910 the crops were sown on land broken late in the autumn of 1909 and in January, 1910. The milos and durras and part of the brown-seeded kaoliangs, including Manchu and Valley, were sown on the later breaking. This did not contain as much moisture as the fall breaking and the crops on it showed the difference to some extent.

In 1911 all varieties except the Blackhull kafirs and the durra-kafir hybrids were sown on sod broken during the previous fall and winter. The two groups named above were on land which had borne a crop of small grain in 1910. In the last five years, 1912 to 1916, inclusive, the grain-sorghum varieties have followed small grains in all cases.

METHODS OF OBTAINING DATA.

The data on plant space and stalk space and on the occurrence of suckers and erect heads have been obtained by actual counts of the plants, stalks, and heads in all the rows of each plat for which such data are given. The percentage of suckers is the difference between the number of stalks and the number of plants, divided by the number of stalks. It is thus a percentage of the total number of stalks in the plat and not a percentage of the number of plants.

The growing period as given here is the total time elapsing from seeding until the grain is ripe. The vegetative period is the first and larger portion of the growing period from seeding until the heads have appeared. If heading is progressing slowly and unevenly the growing period is counted as ending when 50 per cent of the stalks have headed. The ripening period is the complement of the vegetative period and covers the time elapsing between heading and ripening.

The height of the plants is the average of measurements made at several, usually 10, points in the plats.

The varieties are all harvested with a corn binder, leaving a stubble varying in height from 5 to about 8 inches (1 to 2 dm.), depending on the height of the standing plants. The bundles are shocked in the field and allowed to cure for four to six weeks before being thrashed. The shocks are then hauled to the scales and weighed.

The heads are cut from the bundles by means of a large knife fastened to the edge of a box. Very dwarf strains are not headed, but are thrashed in the bundle unless the weight of the heads is desired. Since the stalks often are not of uniform height, the piece of the peduncle or stem left attached to the heads also varies in length. In general it averages about 10 to 12 inches (2.5 to 3 dm.) long. Where it is desired to determine the proportion of heads in the total crop, the heads are weighed before thrashing and the percentage computed.

Thrashing has been done with a small separator. The thrashed seed is weighed as it comes from the separator and the acre yield computed therefrom.

The yields are based on 60 pounds to the bushel of kafir and 58 pounds of all other varieties. After weighing, the thrashed seed is run through a fanning mill and the bushel weight then determined with the standard tester.

Environing Conditions.

To aid in an understanding of the results obtained during the 9-year period from 1908 to 1916, inclusive, a brief summary of seasonal conditions is given and their effects on crop growth and production are noted. Figure 2 shows the annual and seasonal (April to September, inclusive) precipitation during the 10-year period from 1907 to 1916, inclusive.

The season of 1908 was favorable to good yields. The precipitation in the last three months of 1907 was slightly above normal, but in the first three months of 1908 it was considerably below normal. This left little or no stored moisture at the end of March. However, the rainfall in April, May, and June was about normal and fully sufficient for plant growth. With a rainfall of nearly 2 inches above normal in July and August, most of which fell in July, conditions were favorable for a heavy grain yield. Dwarf milo averaged over 41 bushels and Blackhull kafir a little less than 34 bushels per acre.

The season of 1909 was variable and unfavorable. It consisted of a dry spring and a dry summer with a wet June intervening. Precipitation in the winter of 1908–9 was decidedly below normal. The rainfall in March was slightly above normal, but in April and May there was a deficit of 3.5 inches, which left the soil in a very dry condition. June and the first week in July were abnormally wet, inducing strong vegetative growth. From July 8 to the end of August the weather was intensely hot and dry. None of the crops were headed at the time the drought began. The effect of the sudden and severe drought occurring just at this critical stage was to prevent the development of heads on many of the plants, which resulted in low yields of grain. The average yield from the milos was only 6 bushels and from the Dwarf milo 11 bushels. The kafirs, being later, were not so near the critical heading stage when overtaken by drought and were better able to await the fall rains. Their average yield was 12 bushels per acre.

The year 1910 was the driest of the 18 years in which weather data had been recorded at Amarillo. The precipitation during the entire year amounted to only 11.1 inches, or about half of the normal for the 18-year period. Each month in the year was abnormally dry, although the scanty rainfall was fairly well distributed. All but 2 inches fell in the four summer months from May to August, inclusive. However, there was no effective rainfall from May 21 until July 9. The latter half of July also was a period of intense drought, which was continued to the end of the season except for a 10-day period in early August. The droughts of July and August caught both early and late varieties in the critical heading stage and reduced the yields materially, those of the late varieties being most affected. The average acre yield from milo was 17.8 bushels, from Dwarf milo 19 bushels, and from Dawn (dwarf) kafir, a later crop, only 8.9 bushels. The still later standard kafirs were almost completely barren.

The year 1911 was fairly favorable to grain sorghums. The winter of 1910–11 was very dry. There was neither rain nor snow of value until after the middle of February. In the next six weeks, however, the precipitation amounted to about 6 inches, which penetrated the soil to a depth of several feet. Almost 6 inches more had fallen by the end of May. On account of the soaked soil, planting was delayed until June 6. Although June was abnormally dry, the reserve stock of moisture was more than sufficient for crop needs. July was well watered, but a real drought occurred in the first three weeks of August. The average acre yields of all varieties and selections in the best adapted groups were as follows: Milo, 32.3 bushels; Dwarf milo, 37.6 bushels; feterita, 31.9 bushels; and Dawn kafir, 34.9 bushels.

The year 1912 was very dry, the total precipitation being only 14.3 inches. The only rains of consequence were on February 25, June 11, July 30, August 3 and 4, and September 11. This was a fair distribution, but the scanty total and the long drought from June 11 until the end of July reduced yields very much. The average acre yields produced by the leading groups were as follows: Milo, 19 bushels; Dwarf milo, 22.6 bushels; feterita, 24.5 bushels; and Dawn kafir, 9.6 bushels. The standard kafirs averaged less than half as much as the Dawn.

The precipitation of 1913 was only 2 inches below normal and therefore should have been sufficient for the production of good crops. Owing to its very uneven distribution, however, the grain-sorghum crops were almost complete failures. The table of daily precipitation (p. 9) shows that the early summer was dry, that most of the showers of June were too small in quantity to be effective, and that in the three months from June 12 to September 10 only one effective precipitation occurred, namely, that of July 25–28, inclusive. Only the plants at the ends of the rows were able to develop heads under these conditions. The rain of September 10–11 came too late to revive the others, and no yields were obtained.

The year 1914 returned about a half crop. The winter of 1913–14 was unusually wet in its first half and abnormally dry in its second half. January, February, and March, 1914, were "bone" dry. April brought only light showers. The rainfall of May was above normal, but the temperatures at sowing time were low, and rather poor germination resulted. June was remarkably dry, and the scattered rains of the first week in July relieved the suffering plants but temporarily. The drought of the remainder of July cut down the number of heads that were able to emerge, but the rains of early August were sufficient to mature these in spite of the subsequent drought. The average acre yields of the leading groups were as follows: Milo, 11 bushels; Dwarf milo, 26.9 bushels; feterita, 18.5 bushels; and Dawn kafir, 14.7 bushels.

In general, the seasonal conditions in 1915 were good. The total precipitation recorded at the cereal field station was 25.1 inches, while that recorded by the Weather Bureau observer in town was 27.6 inches, a difference of 2.5 inches. Either quantity is sufficient for the growth of these crops, and the distribution was such that growth was not interrupted at any time. While the rainfall in both May and June was below normal, that of April was much above, and the distribution in the two dry months was good. The three succeeding months were abnormally wet. The combined result was the highest yields that have ever been obtained at the Amarillo Cereal Field Station. The average acre yield of all lots of milo was 61.4 bushels; of Dwarf milo, 68.4 bushels; of feterita, 46.9 bushels; of Blackhull kafir, 51.9 bushels; and of Dawn kafir, 53.3 bushels.

The season of 1916 was very dry and unfavorable to the grain sorghums. The total precipitation recorded at the field station was only 16.6 inches, or about 5 inches below normal. While April and June had fair quantities of rain, there was really only one effective rain in each of the four months from April to July, inclusive, and none between June 4 and July 29. The good rains of August did not begin until the 20th, after which there was drought again. It is not surprising, therefore, that low yields were obtained. The average acre yields of the leading groups were as follows: Milo, 7 bushels; Dwarf milo, 8.6 bushels; feterita, 12.2 bushels; and Dawn kafir, 3.7 bushels. Standard kafir failed to mature.

VARIETAL EXPERIMENTS.

The objects of the experiments reported herein were to determine the adaptation and value of the different groups and the best varieties in each group. Studies on the best methods of growing the crop were also made, but the results will appear elsewhere.

Preliminary experiments with two or three varieties had been conducted at Channing, Tex., from 1904 to 1906, inclusive. At Amarillo the work was begun in 1906 by Mr. A. H. Leidigh, in charge of the work with cereals at the Amarillo Cereal Field Station. Three varieties were grown in field plats in 1906, with acre yields as follows: Blackhull kafir, 44.4 bushels; Red kafir, 42.9 bushels; and shallu, 26.1 bushels. In 1907 only two varieties were grown in plats, milo yielding 23.9 bushels and Blackhull kafir 18.9 bushels. Experiments in methods of tillage, rates of seeding, and the improvement of varieties were begun also by Mr. Leidigh.

In 1907 the senior writer began active direction of the experimental work with these crops, and the comprehensive series of varietal and other tests here recorded was planned for the year 1908. The junior writer has been associated in the investigations since July, 1909, and has been acting in charge of the experiments since 1914.

The results obtained from all the lots, selections, and races of all the varieties under experiment in any or all of the nine years from 1908 to 1916, inclusive, are presented in the tables that follow. The importance of the ecologic study of the grain sorghums has been shown in the introduction to this bulletin. The same reasons which require a full presentation of the climatic factors require as well a presentation of all the agronomic data available, so far as they serve to show the comparative response of these crops to environing conditions each season.

The data in the tables include not only the yields, therefore, but many other agronomic data as well. Among them are the average drill-row space occupied by each plant and each stalk; the length, in days, of the vegetative and fruiting periods and of the total growing period, the percentage of suckers, the height of the plants, and, in the milos, the percentage of erect heads. Finally, in some cases, data are given covering the weight of the heads and of the total crop and the proportion by weight of the heads in the total crop and of seed in both heads and total crop.

The different groups of varieties vary considerably in the size of the plants and in earliness and therefore in probable water requirement. From a study of the tables it will be noted that they also vary greatly in their ability to produce from year to year under Panhandle conditions. In the first place, long-season or late-maturing varieties have ripening periods that fall after the warm weather conducive to rapid ripening is well past. Hence, early-maturing varieties are at an advantage. In the second place, in the frequent seasons when the water supply is deficient, dwarf and early varieties with water requirements which are comparatively low or of comparatively short duration are best able to produce good yields.

The tabulated data show clearly that such varieties as milo and Dwarf milo, which are both comparatively early and dwarf, nearly always outyield the larger and later kafirs. Among the kafirs themselves the advantage is always with the earlier and dwarfer varieties.

THE MILO-DURRA GROUP.

The two subgroups and the varieties included in each have been described previously and separated by means of a simple key. These plants are low to midtall, with midsized dry stems and only seven or eight leaves. The heads are broad and comparatively short, either erect or on more or less recurved peduncles. The seeds are either brown or white, broadly oval or sublenticular in outline, and more or less flattened. The group contains two out of the three commercially important varieties, namely, milo and Dwarf milo, the third being Blackhull kafir.

All the varieties, except one or two of the milo hybrids, are early to midearly in maturing. The dry stems ripen with or before the seeds, and the leaves also become dry and often break off and blow away in windy weather. On the whole, the water requirements of the milos and durras are probably as low as those of any of the groups. Their earliness requires that the water supply be maintained during only a comparatively short period. These adaptations give them the power to produce well even in somewhat unfavorable seasons. Their chief handicap is a tendency to produce recurved, or gooseneck, heads in all the varieties except feterita.

The results obtained from the different varieties in this group are presented in Tables VI to XVIII, inclusive. In general, Dwarf milo is the best of all the varieties. Standard milo and feterita rank second, with White milo third.

TABLE VI.—*Agronomic data for standard milo grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

Year and C. I. No.	Row space.		Length of period.			Suckers.	Erect heads.	Heads in crop.	Seed in—		Yields per acre.			
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.				Crop.	Heads.	Total crop.	Heads.	Seed.	
1908:	*Ins.*	*Ins.*	*Days.*	*Days.*	*Days.*	*Perct.*	*Perct.*	*Perct.*	*Perct.*	*Perct.*	*Lbs.*	*Lbs.*	*Lbs.*	*Bus.*
223	8.6	5.0	76	29	105	41.9	70.0	......	......	......	......	......	2,170	37.4
224	......	......	76	29	105	......	......	......	......	......	......	......	2,610	45.0
227	9.0	5.5	76	29	105	38.9	52.3	......	......	......	......	......	1,718	29.6
229	......	......	76	29	105	......	......	......	......	......	......	......	1,763	30.4
230	11.1	5.5	76	29	105	59.5	56.1	......	......	......	......	......	1,955	33.7
231	......	......	76	29	105	......	......	......	......	......	......	......	2,065	35.6
232	8.9	4.8	76	29	105	46.0	65.7	......	......	......	......	......	1,765	30.4
234	9.7	5.1	74	28	102	47.4	53.0	......	......	......	......	......	2,506	43.2
331	8.8	4.9	76	28	105	44.3	68.9	......	......	......	......	......	2,320	33.3
Average	9.3	5.1	75.8	28.8	104.5	46.3	61.0	......	......	......	......	......	2,097	35.4
1909:														
77	13.2	7.4	72	......	......	43.9	98.4	......	......	61.7	......	448	276	4.8
223	14.1	6.0	71	......	......	57.5	97.3	......	......	55.2	......	1,730	955	16.5
224	15.1	6.7	72	......	......	49.3	97.7	......	......	66.9	......	1,165	780	13.5
224-3	13.9	6.3	85	......	......	54.6	96.5	......	......	......	......	......	......	1.8
231	15.9	7.9	83	......	......	50.3	96.0	......	......	......	......	......	......	1.4
232	13.8	7.3	77	......	......	47.0	98.7	......	......	......	......	......	......	3.6
234	12.0	8.1	85	......	......	32.5	97.6	......	......	62.0	......	193	120	2.1
234	12.9	7.3	75	......	......	43.4	98.8	......	......	67.7	......	450	305	5.3
234	11.6	5.8	75	......	......	50.0	98.6	......	......	67.6	......	490	331	5.7
234	8.7	6.1	74	......	......	29.8	98.9	......	......	67.7	......	635	430	7.4
234	6.2	4.7	72	......	......	24.2	99.2	......	......	66.7	......	750	500	8.6
235	11.4	9.0	72	......	......	21.0	96.5	......	......	61.1	......	103	63	1.1
Average	12.4	6.9	76	......	......	41.9	97.8	......	......	64.0	......	663	......	6.0
1910:														
77	26.8	9.9	79	33	112	62.9	62.1	64.8	34.4	53.2	3,194	2,069	1,100	19.0
223-6	32.3	11.9	79	33	112	63.1	63.1	63.1	34.1	54.1	3,189	2,012	1,089	18.8
224	23.0	7.9	77	35	112	65.4	71.7	61.6	32.4	52.6	3,443	2,120	1,115	19.2
227	29.2	9.6	79	28	107	67.0	64.2	67.0	34.5	51.4	3,053	2,045	1,052	18.1
231	30.1	10.1	79	30	109	66.4	61.6	63.6	32.2	50.6	1,415	900	455	7.8
232	22.0	7.7	77	32	109	64.9	77.8	60.1	30.7	51.1	1,844	1,109	567	9.8
234	38.4	13.3	79	33	112	65.5	56.0	......	......	......	......	......	983	17.0
234	21.3	7.8	77	32	109	63.1	72.1	57.6	30.7	53.3	3,444	1,984	1,057	18.2
235	24.6	8.6	77	32	109	65.1	62.2	66.0	34.2	51.8	3,213	2,120	1,098	18.9
329	33.7	10.8	86	26	112	69.4	73.2	......	......	......	......	......	1,125	19.4
343	44.0	13.0	86	26	112	70.5	91.4	......	......	......	......	......	865	14.9
344	58.7	18.0	86	26	112	69.3	58.1	......	......	......	......	......	480	8.3
345	20.0	8.1	79	33	112	59.7	62.7	......	......	......	......	......	1,214	20.9
346	14.9	6.6	76	36	112	55.6	77.8	......	......	......	......	......	1,010	17.4
364	16.9	7.4	77	35	112	56.1	66.5	......	......	......	......	......	1,259	21.7
381	7.1	3.1	80	35	115	55.5	77.6	......	......	......	......	......	1,687	29.1
382	14.5	5.7	85	30	115	60.4	77.6	......	......	......	......	......	1,473	25.4
Average	26.3	9.4	79.8	31.4	111.3	63.5	69.2	62.9	32.9	52.2	2,849	1,795	1,037	17.8
1911:														
77	27.9	10.0	75	37	112	64.3	84.8	54.6	31.2	57.1	5,230	2,860	1,636	28.2
223-6	28.6	11.1	74	37	111	61.1	83.6	54.4	31.1	57.2	4,540	2,470	1,413	24.4
224	33.9	12.3	74	38	111	63.7	78.9	53.4	31.9	59.7	4,290	2,290	1,369	23.6
227	33.4	12.0	74	38	111	64.1	78.5	56.0	36.6	64.5	4,527	2,537	1,637	28.2
231	30.0	10.3	74	38	111	65.1	82.6	52.1	33.9	65.0	5,042	2,632	1,713	29.5
232	25.0	9.5	74	38	111	62.2	89.4	54.6	34.5	63.1	5,050	2,760	1,744	30.1
234	24.1	9.0	74	38	111	62.8	86.0	56.2	34.9	62.2	5,527	3,107	1,932	33.3
234	21.6	9.0	74	38	111	58.6	85.3	56.4	36.6	64.8	5,230	2,960	1,920	33.1
235	19.5	7.3	74	38	111	62.7	90.0	60.9	37.7	61.9	6,042	3,682	2,280	39.3
329	18.5	8.2	74	38	111	55.7	86.2	55.1	35.5	64.5	5,035	2,775	1,792	30.8
343	21.0	8.6	74	38	111	58.7	83.1	61.0	33.2	60.8	5,235	3,195	1,942	33.5
344	20.0	7.7	74	38	111	61.3	80.3	56.6	34.4	60.7	5,680	3,220	1,954	33.7
345	16.0	6.5	74	38	111	59.2	91.2	57.8	37.8	65.4	5,529	3,195	2,091	34.3
346	14.4	5.8	74	38	111	59.5	94.6	59.0	44.8	56.1	5,020	2,960	2,225	38.4
364	12.8	5.0	74	38	111	61.3	96.5	56.6	35.0	61.7	6,042	3,422	2,116	36.5
381	13.2	4.5	74	38	111	65.8	97.4	57.4	34.3	61.8	6,160	3,540	2,114	36.4
382	14.3	5.2	76	36	111	63.4	96.1	51.0	30.5	59.1	6,455	3,335	1,790	30.9
468	12.3	5.2	74	36	111	58.9	95.1	59.7	35.1	58.9	5,867	3,507	2,077	35.8
469	11.4	4.7	76	36	111	58.5	98.0	53.6	30.8	57.6	6,307	3,367	1,942	33.5
Average	20.9	7.2	74.2	37.5	111	61.4	88.3	56.1	34.7	61.2	5,412	3,043	1,878	32.3

TABLE VI.—*Agronomic data for standard milo grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive*—Continued.

Year and C. I. No.	Row space.		Length of period.						Seed in—		Yields per acre.			
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.	Suckers.	Erect heads.	Heads in crop.	Crop.	Heads.	Total crop.	Heads.	Seed.	
	Ins.	*Ins.*	*Days.*	*Days.*	*Days.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Lbs.*	*Lbs.*	*Lbs.*	*Bus.*
1912:														
77	7.1	3.3	72	35	107	52.9	97.5	54.9	34.7	63.1	5,360	2,945	1,861	32.1
223-6	8.5	3.6	72	35	107	57.0	96.5	49.5	26.9	54.2	5,090	2,523	1,370	23.6
224	8.9	3.5	72	35	107	61.2	95.6	51.8	28.3	58.3	5,290	2,743	1,499	25.8
227	7.5	3.5	72	35	107	53.6	99.0	56.5	34.1	60.3	4,920	2,783	1,679	29.0
231	7.2	3.4	72	35	107	53.1	97.0	54.8	31.8	58.1	5,460	2,992	1,739	29.7
232	6.5	3.5	72	35	107	47.1	99.0	55.4	33.4	60.2	5,740	3,185	1,919	33.0
234	6.3	3.4	72	35	107	46.1	98.1	54.7	31.1	56.8	4,330	2,371	1,349	23.3
234	7.1	3.6	75	32	107	50.1	98.0	53.0	25.6	52.9	4,020	2,134	1,130	19.5
235	6.6	3.1	75	32	107	52.4	99.0	......	21.8	......	3,152	......	688	11.9
329	7.0	4.4	75	32	107	37.0	99.0	......	31.7	......	2,995	......	951	16.4
343	7.3	3.5	75	32	107	52.0	98.1	......	29.4	......	3,635	......	1,071	18.5
344	8.3	3.7	75	32	107	55.1	97.5	......	33.3	......	3,635	......	1,210	20.9
346	6.3	3.5	75	32	107	44.5	98.2	......	28.0	......	3,243	......	109	15.7
364	7.3	3.5	75	32	107	52.2	98.0	......	25.5	......	2,973	......	759	13.1
381	7.3	3.3	90	[a]17	107	54.3	96.5	......	13.1	......	1,571	......	207	3.6
468	6.1	3.5	90	[a]17	107	43.0	94.0	......	6.1	......	1,410	......	87	1.5
469	7.3	3.5	90	[a]17	107	52.0	98.0	......	13.4	......	2,130	......	287	5.0
Average	7.2	3.5	76.3	30.5	107	50.7	97.5	53.8	26.3	57.9	3,821	2,709	1,101	19.0
1913:														
77	6.3	3.6	71	31	102	43.4	......	......	......	......	......	......	......	......
223-6	5.6	3.6	71	31	102	35.1	......	......	......	......	......	......	......	......
224	6.5	3.6	71	31	102	45.0	......	......	......	......	......	......	......	......
227	5.7	3.6	71	31	102	36.5	......	......	......	......	......	......	......	......
231	5.3	3.3	71	31	102	36.5	......	......	......	......	......	......	......	......
232	5.7	3.4	71	31	102	39.8	......	......	......	......	......	......	......	......
234	5.5	3.6	71	31	102	34.2	......	......	......	......	......	......	......	......
234	5.7	3.9	71	31	102	32.8	......	......	......	......	......	......	......	......
235	5.4	3.8	71	31	102	30.5	......	......	......	......	......	......	......	......
329	5.7	4.3	71	31	102	24.7	......	......	......	......	......	......	......	......
343	5.9	4.0	71	31	102	32.4	......	......	......	......	......	......	......	......
344	5.8	3.2	71	31	102	47.4	......	......	......	......	......	......	......	......
346	5.4	3.4	71	31	102	37.4	......	......	......	......	......	......	......	......
364	4.9	3.3	71	31	102	27.9	......	......	......	......	......	......	......	......
381	4.4	3.0	71	31	102	32.6	......	......	......	......	......	......	......	......
468	6.2	3.7	71	31	102	40.5	......	......	......	......	......	......	......	......
469	5.7	3.5	71	31	102	39.5	......	......	......	......	......	......	......	......
505	9.5	4.2	71	31	102	55.4	......	......	......	......	......	......	......	......
Average	5.8	3.6	71	31	102	37.3	......	......	......	......	......	......	......	......
1914:														
77	13.0	5.1	68	23	91	60.6	97.8	......	11.7	......	4,120	......	480	8.3
223	13.5	5.5	68	23	91	59.6	99.0	......	17.3	......	4,280	......	740	12.8
232	12.3	5.0	68	23	91	59.4	98.7	......	16.8	......	3,680	......	620	10.7
234	12.1	4.3	68	23	91	64.0	99.1	......	19.6	......	4,400	......	860	14.8
235	13.9	5.1	68	23	91	63.6	99.8	......	13.2	......	3,800	......	500	8.4
Average	13.0	5.0	68	23	91	61.4	98.9	......	15.7	......	4,056	......	640	11.0
1915:														
77	15.1	4.8	75	44	119	67.9	90.0	45.0	31.9	70.9	10,220	4,600	3,260	56.2
223	16.0	5.4	75	44	119	66.0	90.0	49.4	43.8	88.7	8,580	4,240	3,760	64.8
232	13.2	4.6	75	44	119	65.1	95.5	43.5	35.1	80.5	9,920	4,320	3,480	60.0
234	16.2	5.1	75	44	119	65.1	91.8	50.1	40.5	80.9	8,380	4,200	3,400	58.6
235	17.8	5.3	75	44	119	69.3	84.7	50.1	41.9	83.7	9,340	4,680	3,920	67.6
Average	15.7	5.1	75	44	119	66.7	90.4	47.6	38.6	80.9	9,288	4,408	3,564	61.4
1916:														
77	6.5	3.4	82	32	114	46.9	96.4	......	11.9	......	3,180	......	380	6.6
223	7.0	3.9	82	32	114	44.0	93.7	......	12.3	......	3,580	......	440	7.6
232	7.9	4.3	82	32	114	46.2	98.6	......	11.9	......	3,200	......	380	6.6
234	7.3	3.8	83	31	114	47.6	95.6	......	13.5	......	2,960	......	400	6.9
235	8.2	4.2	83	31	114	49.2	94.6	......	15.8	......	2,660	......	420	7.2
Average	7.4	3.9	82.4	31.6	114	46.8	95.8	......	13.1	......	3,116	......	404	7.0

[a] Plants killed by drought at this stage.

MILO.

The crop now grown commercially under the name of milo in the southern half of the Great Plains area is a descendant of the old milo, or "Giant milo," which was the original grain-sorghum crop of Texas. It has been considerably improved by the writers through selection for lower stature, earliness, and more uniformly erect heads. The number of different lots and selections under experiment has varied from as many as 19 in the year 1911 to only 5 during each of the last three years. The different lots vary little among themselves, as will be seen by comparing their average performances in Tables VI and VII. The total number of plats grown in the 9-year period was 107. Plats of milo and Dwarf milo are shown in figure 4.

A study of Table VI will show that, under fairly favorable conditions, when acre yields run from 18 to 40 bushels, as in 1908 and 1910, the average vegetative period of milo covers about 75 days. Under varying seasonal conditions it has ranged from as few as 68 days, in 1914, to as many as 82 days, in 1916. Drought occurring very early in the vegetative period results in slower growth and consequent prolongation of this period. This is seen in the seasons of 1910 and 1916. The apparent shortening of the vegetative period in 1914 was due to the fact that only a few early heads appeared, further development being checked by drought.

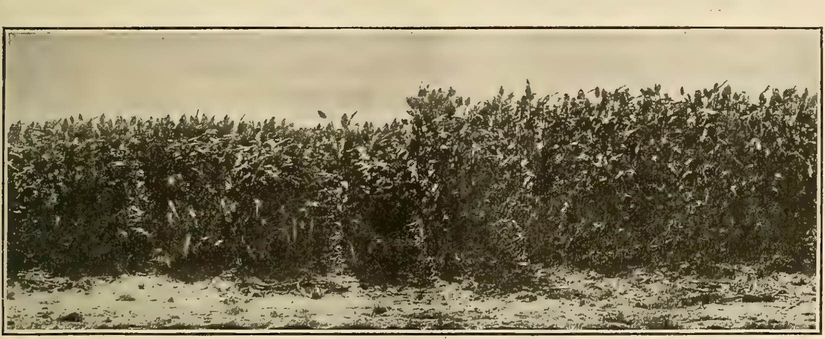

FIG. 4.—Milo (right) and Dwarf milo (left) in plats at the Amarillo Cereal Field Station, August 30, 1911.

The ripening period of milo usually covers a little less than 30 days, as in the fairly normal season of 1908. It was shortened to only 23 days by the droughty conditions prevailing in 1914, the year in which only a few heads were produced. The ripening period may be prolonged, however, by conditions favorable to good yields. In 1911, for instance, the average duration of this period was 37.5 days, owing apparently to heavy rains just at the time of heading, as this was followed by dry and very hot weather throughout the ripening period. The average acre yield was 32.3 bushels. In 1915 the extremely prolonged ripening period of 44 days is correlated with very cool, wet weather during the last three weeks of August, which was coincident with the first half of this period. The duration of the total growing period is about 105 to 110 days under Panhandle conditions. The shortest duration of the growing period was 91 days, in 1914, and the longest was 119 days, in 1915. The first was a dry season, marked by much reduced yields; the second a very wet season in which enormous yields were obtained.

The average row space intended for each plant of milo under Panhandle conditions is about 6.5 inches. Approximately this spacing has been obtained three times in the 9-year period, in the years 1912, 1913, and 1916. In the four years, 1908, 1909, 1914, and 1915, the spacing has varied between 9 and 16 inches, while in the other two years, 1910 and 1911, the stands obtained were very thin, the plants being 26.3 and 20.9 inches apart, respectively, in the two years. The average spacing of plants during the nine years has been 13.7 inches. The stands vary somewhat with the conditions at sowing time. Either a cold, wet spring or an extremely dry soil may reduce germination and consequent stand. Dry soil was the cause in 1910, but the exact cause in 1911 is not known, as the stands of Dwarf milo and Blackhull kafir were not markedly reduced that year.

The average stalk space is determined by conditions occurring during the progress of the early vegetative period and influencing the production of suckers. The average space in inches per stalk varies less than the space per plant, which shows the adaptation of these plants to equalize stand by means of tillering. The average stalk space in all plats in the nine years has been 5.7 inches, and only once has it appreciably exceeded 7 inches. This exception was in the year 1910, when the same drought that lowered germination also inhibited excessive tillering. The percentage of suckers in the total number of stalks varied from 37.3 in 1913, when a thick stand was accompanied by a dry growing season, to 66.7 per cent in 1915, when a fairly thin stand and excessive moisture both conduced to abundant tillering. In five out of the nine years, more than half the total stalks were suckers. In three of these years the yields were below normal. In the 9-year period 52.3 per cent of the total number of stalks were suckers. It is a question whether the free tillering of milo is wholly an advantage. Were it less pronounced the crop probably could make better yields in seasons of deficient moisture. The average height of milo under conditions obtaining in the Panhandle is about 4 feet.

The average of erect heads in milo in eight years was 86.9 per cent. Practically no heads were produced in 1913. The lowest average was 61 per cent, in 1908. In four of the eight years more than 95 per cent of the heads were erect. The proportion of erect heads is influenced by the vigor of the plants at and after heading time. A low percentage of erect heads is correlated with good rains in the first half of August in 1908 and 1910, but not in 1914, when a drought in July had weakened the plants too much to permit response to the improved conditions.

Milo has made a very good average yield, 22.7 bushels of 58 pounds each per acre, in the 9-year period under consideration. The average is based on the yields from no less than 107 plats in the nine years. Table VII contains the annual and average acre yields of all lots grown. According to the figures in Tables VI and VII, the lowest average annual acre yields have been 0 in 1913, 6 bushels in 1909, and 7 bushels in 1916. The highest have been 61.4 bushels in 1915, 35.4 in 1908, and 32.3 bushels in 1911. The nine annual yields may be classified as one failure, three poor, two fair, two good, and one excellent. This probably is not far from what may be expected to occur in any period of similar duration. The 9-year average acre yields of the three lots grown during that period were 22.9, 22.4, and 20.5 bushels, respectively.

TABLE VII.—*Annual and average acre yields of all lots of standard milo grown at the Amarillo Cereal Field Station during periods of varying length in the nine years from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

C. I. No.	Annual yields (bushels).									Average yields.				
	1908	1909	1910	1911	1912	1913	1914	1915	1916	4 years, 1910 to 1913.	6 years, 1908 to 1913.	8 years, 1909 to 1916.	9 years, 1908 to 1916.	
										Bus.	*Bus.*	*Bus.*	*Bus.*	*Cwt.*
77	......	4.8	19.0	28.2	32.1	0	8.3	56.2	6.6	19.8	......	19.4	......	......
223	37.4	16.5	18.8	24.4	23.6	0	12.8	64.8	7.6	16.7	20.1	21.1	22.9	13.3
224	45.0	[a] 7.6	19.2	23.6	25.8	0	......	......	......	17.2	20.0	......	......	......
227	29.6	......	18.1	28.2	29.0	0	......	......	......	18.8	......	......	......	......
229	30.4	......	......	......	......	......	......	......	......	......	......	......	......	......
230	33.7	......	......	......	......	......	......	......	......	......	......	......	......	......
231	35.6	1.4	7.8	29.5	29.7	0	......	......	......	16.7	17.3	......	......	......
232	30.4	3.6	9.8	30.1	33.0	0	10.7	60.0	6.6	18.2	17.8	19.2	20.5	11.0
234	43.2	[b] 5.8	[a]17.6	[a]33.2	[a]21.4	0	14.8	58.6	6.9	18.1	20.2	19.8	22.4	13.2
235	......	1.1	18.9	39.3	11.9	0	8.4	67.6	7.2	17.5	......	19.3	......	......
329	......	......	19.4	30.8	16.4	0	......	......	......	16.5	......	......	......	......
331	33.3	......	......	......	......	......	......	......	......	......	......	......	......	......
343	......	......	14.9	33.5	18.5	0	......	......	......	16.7	......	......	......	......
344	......	......	8.3	33.7	20.9	0	......	......	......	15.7	......	......	......	......
345	......	......	20.9	34.3	......	......	......	......	......	......	......	......	......	......
346	......	......	17.4	38.4	15.7	0	......	......	......	17.9	......	......	......	......
364	......	......	21.7	36.5	13.1	0	......	......	......	17.8	......	......	......	......
381	......	......	29.1	36.4	3.6	0	......	......	......	17.3	......	......	......	......
382	......	......	25.4	30.9	......	......	......	......	......	......	......	......	......	......
468	......	......	......	35.9	1.5	0	......	......	......	......	......	......	......	......
469	......	......	......	33.5	5.0	0	......	......	......	......	......	......	......	......
Average	35.4	6.0	17.8	32.3	19.0	0	11.0	61.4	7.0	......	......	......	......	......

[a] Average of two plats.

[b] Average of five plats.

DWARF MILO.

Dwarf milo is essentially a dwarf form of the ordinary standard milo, differing chiefly in its lower stature. (See fig. 4.) Its origin is not known, but probably it was derived from a mutation of standard milo. Different selections of it have been grown throughout the 9-year period covered by these experiments. Considerable selection has been practiced by the writers to improve it in uniformity of height and ripening and to obtain more highly productive races. The number of selections under experiment increased from 5 in 1908 to 17 in 1910, decreasing thereafter to 5 again in each of the last three years. A total of 90 plats has been grown in the nine years. A plat grown in 1915 is shown in figure 5.

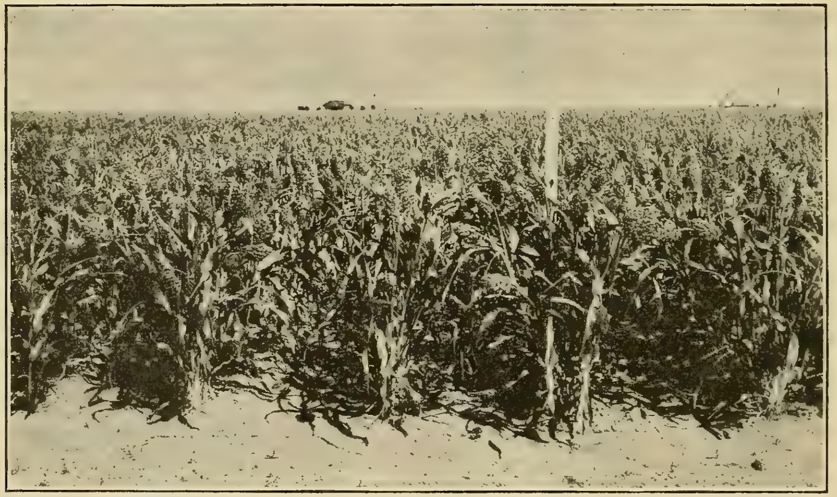

FIG. 5.—A plat of Dwarf milo, C. I. No. 332, at the Amarillo Cereal Field Station, September 14, 1915; yield, 72.8 bushels per acre.

Dwarf milo has about the same growth period as standard milo and therefore is affected by the same climatic conditions at about the same stages of development. A study of the data on vegetative and fruiting periods in Tables VI and VIII shows a close correspondence between its variations and those of standard milo. The average duration of the vegetative period of Dwarf milo in all years is 73.5 days, or about 2 days shorter than that of milo. The shortest average duration was 65 days, in 1914, and the longest was 79 days, in 1916. Both these extremes are lower than those of milo, but occur in the same years. The average duration of the fruiting period of all plats in the eight years in which the crop matured was 33.2 days, or 0.9 of a day longer than that of milo. The fruiting period was only 26 days in 1914, but was increased to 45 days in 1915, these periods being 3 days and 1 day longer, respectively, than those of milo in the same years.

TABLE VIII.—*Agronomic data for Dwarf milo grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

Year and C. I. No.	Row space.		Length of period.			Suckers.	Erect heads.	Height of plants.	Seed in crop.	Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Total crop.	Seed.	
1908:	*Inches.*	*Inches.*	*Days.*	*Days.*	*Days.*	*Per cent.*	*Per cent.*	*Feet.*	*Per cent.*	*Lbs.*	*Lbs.*	*Bus.*
149A	8.4	4.0	76	29	105	52.4	73.8	3.5	......	......	2,190	37.8
149B	8.3	3.5	76	31	107	57.8	57.0	3.5	......	......	2,687	46.3
149C	9.0	3.8	76	29	105	57.7	58.7	3.5	......	......	2,543	43.8
332A	8.3	4.3	76	28	104	48.2	63.1	3.5	......	......	2,262	39.0
332B	9.1	4.1	76	28	104	54.9	......	3.5	......	......	2,316	39.9
Average	8.6	3.9	76	29	105	54.2	63.1	3.5	......	......	2,400	41.3
1909:												
149-5	11.4	7.5	73	......	......	34.2	99.4	......	......	......	......	10.2
149-6	12.1	9.8	73	......	......	23.1	99.5	......	......	......	......	7.9
149	11.7	7.7	70	......	......	33.3	99.4	......	......	......	......	19.1
236	13.5	7.2	78	......	......	46.7	99.3	......	......	......	......	5.8
236	12.2	6.5	74	......	......	46.6	98.8	......	......	......	......	3.2
236	8.7	4.8	73	......	......	44.8	99.4	......	......	......	......	6.5
332	11.0	7.7	73	......	......	30.0	99.4	......	......	......	......	10.0
332	10.8	7.7	73	......	......	28.7	99.2	......	......	......	......	10.6
332	13.1	7.2	70	......	......	45.0	98.8	......	......	......	......	23.2
332	14.9	9.0	70	......	......	39.6	99.4	......	......	......	......	13.4
Average	11.8	7.3	72.7	......	......	37.2	99.3	......	......	......	......	11.0
1910:												
149-5	22.8	8.0	77	35	112	66.0	67.6	2.5	39.9	2,898	1,156	19.9
149-6	25.3	8.1	79	33	112	68.1	63.8	2.7	39.8	3,140	1,251	21.6
149-6	20.9	7.7	79	33	112	63.3	69.7	2.5	38.7	3,140	1,216	21.0
184	25.7	8.3	77	35	112	68.4	63.8	2.5	40.9	2,724	1,115	19.2
236	26.1	8.1	77	35	112	69.1	70.0	2.7	38.7	2,786	1,078	18.6
332A	33.2	11.1	79	33	112	66.5	57.6	2.7	41.7	2,507	1,046	18.0
332B	19.2	6.7	79	33	112	64.8	67.0	2.7	38.6	2,862	1,106	19.1
347	18.1	7.3	76	36	112	59.8	72.3	3.0	......	......	1,055	18.2
348	18.0	7.0	76	36	112	60.9	64.4	2.7	......	......	1,195	20.6
357	17.8	6.8	79	33	112	61.7	64.6	2.7	......	......	1,035	17.8
358	12.3	6.0	76	36	112	51.0	75.7	2.7	......	......	1,045	18.0
359	11.1	5.8	76	36	112	47.7	76.4	2.7	......	......	1,158	20.0
360	12.1	6.0	79	33	112	50.3	73.4	2.5	......	......	961	16.6
361	10.1	4.9	77	35	112	51.9	79.1	2.7	......	......	1,127	19.4
362	14.1	5.9	76	36	112	58.0	76.2	3.2	......	......	1,212	20.9
363	16.9	6.6	79	33	112	60.6	73.4	2.5	......	......	1,061	18.3
368	16.8	6.6	77	35	112	60.9	72.3	2.7	......	......	932	16.1
Average	18.8	7.1	77.5	34.4	112	60.5	69.8	2.7	39.8	2,865	1,103	19.0
911:												
149-5	8.9	3.7	73	37	110	58.5	98.5	5.0	31.9	6,525	2,085	36.0
149-6	11.4	3.9	73	37	110	65.4	98.4	4.7	32.9	6,587	2,172	37.5
184	10.6	4.0	73	37	110	62.2	97.7	5.0	34.3	6,294	2,160	37.3
236	10.8	4.1	73	37	110	61.7	97.4	4.7	34.8	6,347	2,212	38.1
332	10.5	4.2	72	37	109	59.8	98.1	4.7	35.3	6,138	2,167	37.4
347	10.8	4.3	72	37	109	60.2	98.8	4.7	35.9	6,294	2,260	38.9
348	9.5	4.4	74	35	109	53.7	98.4	4.7	37.6	5,955	2,240	38.6
357	11.2	4.0	74	35	109	63.0	97.2	4.7	39.1	6,317	2,472	42.6
358	11.7	4.4	74	35	109	62.6	97.5	4.7	37.7	6,080	2,294	39.6
359	10.9	4.5	74	35	109	59.0	97.3	4.7	37.8	5,720	2,164	37.3
360	12.3	4.9	74	35	109	60.5	97.0	4.7	37.9	5,554	2,110	36.4
361	9.8	4.9	74	35	109	61.1	98.2	4.7	33.0	6,337	2,092	36.1
362	10.7	4.4	74	35	109	58.3	98.6	5.0	33.1	6,360	2,074	35.8
363	10.4	3.9	74	35	109	62.4	98.8	5.0	33.8	6,114	2,070	35.7
368	12.1	4.4	74	35	109	65.2	98.1	5.0	33.7	6,375	2,150	37.1
Average	10.8	4.3	73.4	35.8	109.2	60.9	98.0	4.8	35.3	6,200	2,181	37.6
912:												
149-5	6.4	3.4	75	32	107	46.9	97.8	2.5	30.6	1,982	608	10.5
149-6	7.3	3.5	75	32	107	52.0	96.4	2.5	35.0	2,653	929	16.0
184	5.9	3.2	75	32	107	46.2	98.3	2.5	33.3	2,571	858	14.8
236	4.5	2.8	78	29	107	38.1	98.6	2.5	28.4	2,283	649	11.2
332B	6.5	3.1	72	35	107	51.8	98.2	2.5	40.1	3,483	1,399	24.0
347	4.5	2.5	75	32	107	44.0	99.0	2.5	34.9	3,173	1,109	19.1

TABLE VIII.—*Agronomic data for Dwarf milo grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive*—Continued.

Year and C. I. No.	Row space.		Length of period.			Suckers.	Erect heads.	Height of plants.	Seed in crop.	Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Total crop.	Seed.	
1912—Contd.	*Inches.*	*Inches.*	*Days.*	*Days.*	*Days.*	*Per cent.*	*Per cent.*	*Feet.*	*Per cent.*	*Lbs.*	*Lbs.*	*Bus.*
348	5.8	3.2	75	32	107	44.9	98.1	2.5	40.3	3,693	1,489	25.7
357	5.9	3.2	72	35	107	45.1	95.6	2.5	43.4	3,933	1,709	29.5
358	6.0	3.5	74	32	106	41.0	98.0	2.8	45.3	4,035	1,831	31.6
359	5.7	3.4	71	35	106	39.5	98.6	2.8	45.9	4,373	2,009	34.6
360	5.4	3.4	74	32	106	36.3	98.5	2.8	36.8	3,493	1,289	22.2
361	8.6	3.4	74	32	106	60.1	97.2	2.8	42.6	3,213	1,369	23.6
362	7.3	3.3	74	32	106	55.5	97.6	2.8	40.8	3,252	1,328	22.9
363	7.3	3.4	74	32	106	53.5	97.6	2.8	43.1	3,453	1,489	25.7
368	6.8	3.2	74	32	106	53.2	98.0	2.8	39.7	3,693	1,469	25.3
487	6.2	3.3	74	32	106	46.8	98.0	2.8	43.1	3,453	1,489	25.7
Average	6.3	3.2	74.1	32.3	106.5	47.0	97.8	2.6	38.9	3,296	1,314	22.6
1913:												
149-5	4.4	3.2	70	30	100	27.1	......	1.7	......	......	......	......
149-6	4.5	3.2	70	30	100	28.2	......	1.7	......	......	......	......
184	4.9	3.4	70	30	100	29.9	......	1.7	......	......	......	......
236	4.8	3.1	70	30	100	34.6	......	1.7	......	......	......	......
332B	4.9	3.4	70	30	100	30.4	......	1.7	......	......	......	......
347	4.7	3.4	70	30	100	28.1	......	1.7	......	......	......	......
348	4.9	3.3	70	30	100	32.4	......	1.7	......	......	......	......
357	4.7	3.4	70	30	100	29.1	......	1.7	......	......	......	......
358	4.5	3.4	70	30	100	24.5	......	1.7	......	......	......	......
359	5.6	3.7	70	30	100	34.8	......	1.7	......	......	......	......
360	4.6	3.2	70	30	100	31.4	......	1.7	......	......	......	......
361	5.1	3.5	70	30	100	31.4	......	1.7	......	......	......	......
362	4.6	3.3	70	30	100	27.4	......	1.7	......	......	......	......
363	4.4	3.2	70	30	100	25.8	......	1.7	......	......	......	......
368	5.0	3.5	70	30	100	30.6	......	1.7	......	......	......	......
487	4.5	3.3	70	30	100	27.0	......	1.7	......	......	......	......
504	4.9	3.3	70	30	100	31.2	......	1.7	......	......	......	......
Average	4.8	3.3	70	30	100	29.6	......	1.7	......	......	......	......
1914:												
149-5	9.2	4.1	65	26	91	55.4	99.2	3.0	30.2	5,760	1,740	30.0
236	10.0	4.2	65	26	91	58.4	99.6	3.0	32.5	5,600	1,800	31.0
332	7.1	3.8	65	26	91	47.2	99.8	3.0	32.4	5,440	1,760	30.3
347	9.1	3.8	65	26	91	58.6	99.7	3.0	29.5	5,360	1,580	27.1
359	11.4	4.5	65	26	91	60.6	99.4	2.8	24.7	3,800	940	16.2
Average	9.4	4.1	65	26	91	56.0	99.5	3.0	29.8	5,192	1,564	26.9
1915:												
149	13.2	4.5	74	45	119	66.0	87.2	4.5	31.9	......	......	......
236	12.6	4.3	74	45	119	65.9	89.1	4.5	43.8	12,480	3,640	62.7
332	12.1	4.5	74	45	119	63.0	91.6	4.5	35.1	10,380	4,080	70.3
347	13.2	3.9	74	45	119	70.4	94.5	4.5	40.5	8,340	4,200	72.4
359	14.1	3.5	74	45	119	67.9	92.4	4.5	41.9	9,400	3,960	68.3
Average	13.0	4.1	74	45	119	66.6	91.0	4.5	38.6	10,150	3,970	68.4
1916:												
149	7.0	3.5	78	36	114	50.3	99.1	2.3	20.9	2,100	440	7.6
236	7.3	3.7	78	36	114	49.8	98.6	2.3	21.7	1,840	400	6.9
332	7.7	3.7	78	36	114	52.6	100.0	2.3	27.2	2,060	560	9.7
347	7.6	3.7	80	33	113	50.7	99.4	2.3	26.5	2,260	600	10.3
359	7.2	3.7	82	32	114	48.9	99.4	2.3	22.3	2,240	500	8.6
Average	7.4	3.7	79	34	114	50.5	99.3	2.3	23.7	2,100	500	8.6

The length of the total growing period, averaged for all plats in all eight years, is practically identical for both milo and Dwarf milo, being 106.5 and 106.9 days, respectively. The shortest growing period recorded was 91 days, in 1914, and the longest 119 days, in 1915. The growing periods of milo were of exactly the same duration as those of Dwarf milo in these two years. The total growing period of both varieties was made to appear very short in 1914, owing to the drought, which inhibited the production of all but a few early heads.

In 1915 the vegetative period was about normal and the fruiting period greatly lengthened in both, and in 1916 both periods were somewhat prolonged in both varieties.

Table VIII shows that the average drill-row space per plant of Dwarf milo in all plats during the whole nine years has been 10.3 inches. The variation from year to year has not been quite so great as it was in the milo. The annual averages range from 4.8 inches in 1913 to 18.8 inches in 1910. The next poorest stand was in 1915, when each plant had 13 inches of space. Milo had a stand of one plant to each 15.7 inches in the same year. In 1911, when milo had only one plant to each 20.9 inches, Dwarf milo had one plant to each 10.8 inches, or nearly twice the stand of milo. No reason for the difference is known.

The average stalk space in the total of 90 plats grown in the nine years was 4.7 inches, compared with 5.7 inches for all milo plats. The average plant space in the same period was 10.3 inches for Dwarf milo and 13.7 inches for milo. These bear about the same proportion to each other as the respective stalk spaces. Of all Dwarf milo stalks in all years, 49.5 per cent were suckers, while 52.3 per cent of the milo stalks were suckers under the same conditions. In short, the milo plants on the average had 3.4 inches, or about 35 per cent, more space than the Dwarf milo plants, but produced only about 5.6 per cent more suckers. In the different years the stalk space varied from 3.2 inches, in 1912, to 7.3 inches, in 1909. It is of interest that the total failure of 1913, the average acre yield of 41.3 bushels in 1908, and the bumper acre yield of 68.4 bushels in 1915 should be associated with stands of one stalk to each 3.3, 3.9, and 4.1 inches of space, respectively. In the latter year exactly two-thirds of the stalks were suckers. In other words, with a stand of one plant to each 13 inches each stalk produced two suckers on the average under the influence of the very favorable wet season.

On all plats in all years the average percentage of erect heads was 89.8 per cent, compared with 86.9 in milo. In five out of the eight years in which heads were formed, more than 97 per cent were erect. In the favorable season of 1908, only 63.1 per cent were erect, while in the very favorable wet season of 1915, 91 per cent were erect. This increased erectness in 1915 probably was due to the continued selection for erect heads and the effect of the extremely heavy seed crop in suppressing what otherwise would have been excessive vegetative vigor.

The average height of Dwarf milo in all 90 plats in all nine years was 3 feet, compared with an average of 4 feet for milo. There was an enormous variation in average height from year to year. For instance, in 1916 the average height was only 2.3 feet, and in 1912 but 2.6 feet. In 1915, however, under the influence of abundant rainfall, it rose to 4.5 feet, and in 1911 to 4.8 feet. The average height of 1.7 feet, recorded in 1913, included many stalks which bore no heads and therefore had not attained full height.

The most important character of Dwarf milo is its outstanding ability to produce good yields, as shown in Tables IX and XVIII. The average acre yield from all the 90 plats grown in the nine years has been 26.2 bushels. Under the same conditions, the average acre yield from 107 plats of milo was 22.7 bushels. The lowest average yield recorded, except the complete failure of 1913, is 8.6 bushels, in 1916. The highest is 68.4 bushels, in 1915. In the same years milo yielded 7 and 61.4 bushels, respectively. The yields of this variety obtained during the nine years of the experiment may be classified as follows: One failure, two poor, three fair, two good, and one superexcellent.

TABLE IX.—*Annual and average acre yields of all lots of Dwarf milo grown at the Amarillo Cereal Field Station during periods of varying length in the nine years from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

C. I. No.	Annual yields (bushels).									Average yields.				
	1908	1909	1910	1911	1912	1913	1914	1915	1916	4 years, 1910 to 1913.	7 years, 1910 to 1916.	8 years, 1909 to 1916.	9 years, 1908 to 1916.	
										Bus.	*Bus.*	*Bus.*	*Bus.*	*Cwt.*
149	[a]42.6	[a]12.4	[a]20.8	[b]36.8	[b]13.3	0	30.0	74.1	7.6	17.7	26.1	24.4	26.4	15.3
184	......	......	19.2	37.3	14.8	0	......	......	......	17.8	......	......	......	......
236	......	[a]5.2	18.6	38.1	11.2	0	31.0	62.7	6.9	16.9	24.1	21.7	......	......
332	[b]39.5	[c]14.3	[b]18.6	37.4	24.0	0	30.3	70.3	9.7	20.0	27.2	25.6	27.1	15.7
347	......	......	18.2	38.9	19.1	0	27.1	72.4	10.3	19.1	26.6	......	......	......
348	......	......	20.6	38.6	25.7	0	......	......	......	21.2	......	......	......	......
357	......	......	17.8	42.6	29.5	0	......	......	......	22.5	......	......	......	......
358	......	......	18.0	39.6	31.6	0	......	......	......	22.3	......	......	......	......
359	......	......	20.0	37.3	34.6	0	16.2	68.3	8.6	22.9	26.4	......	......	......
360	......	......	16.6	36.4	22.2	0	......	......	......	18.8	......	......	......	......
361	......	......	19.4	36.1	23.6	0	......	......	......	19.8	......	......	......	......
362	......	......	20.9	35.8	22.9	0	......	......	......	19.9	......	......	......	......
363	......	......	18.3	35.7	25.7	0	......	......	......	19.9	......	......	......	......
368	......	......	16.1	37.1	25.3	0	......	......	......	19.6	......	......	......	......

[a] Average yield from three plats. [b] Average yield from two plats. [c] Average yield from four plats.

The 9-year average acre yields of two lots grown during that period are 27.1 and 26.4 bushels, respectively. The yield of the best one is 4.2 bushels more than the yield of the best milo in the same period, as shown in Table XVIII. In figure 6 the annual yields of the best race (C. I. No. 332) during the nine years from 1908 to 1916, inclusive, are shown in graphic form, together with the seasonal (May to August) and annual precipitation during the same period.

ALBA, OR WHITE, MILO.

The variety Alba, or White, milo, is an exact counterpart of the ordinary standard milo except in the color of the seed, which is white instead of brown. The early history of this variety is not known. It probably was introduced about 25 or 30 years ago. It was found under cultivation in scattered localities in western Texas, in 1909, during an extensive reconnaissance made by the senior writer. It has since been found sparingly in Oklahoma. Five different lots were obtained in 1909 and included in the experiments in 1910. The number was increased to nine in 1912, but during the last three seasons only two lots have been grown. A total of 34 plats have been grown in the seven years. The results obtained are given in Tables X and XI. The Alba milo is so similar to milo in its adaptations and reactions to environment that extended comment upon the results seems unnecessary.

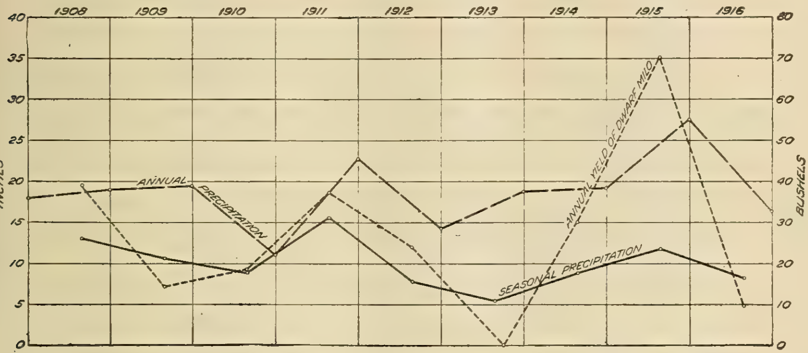

FIG. 6.—Diagram showing the seasonal (May to August) and annual precipitation, in inches, and the acre yield of Dwarf milo (C. I. No. 332), in bushels, at the Amarillo Cereal Field Station in each of the nine years from 1908 to 1916, inclusive.

The extremely prolonged ripening period in 1910 was due to the very thin stand, which permitted free tillering, there being 70.8 per cent of suckers in the total number of stalks. The many late-appearing suckers matured slowly, thus prolonging the ripening an extra 10 days. Only 60. 7 per cent of erect heads resulted. The thin stand was due, in turn, to the immature condition of part of the seed obtained in 1909, as the exploring trip was made before these crops were ripe.

TABLE X.—*Agronomic data for White milo grown at the Amarillo Cereal Field Station during the 7-year period from 1910 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

Year and C. I. No.	Row space.		Length of period.							Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.	Suckers.	Erect heads.	Height of plants.	Heads in crop.	Crop.	Heads.	Total crop.	Heads.	Seed.
	Ins.	*Ins.*	*Days.*	*Days.*	*Days.*	*Per cent.*	*Per cent.*	*Feet.*	*Per cent.*	*Per cent.*	*Per cent.*	*Lbs.*	*Lbs.*	*Bus.*
1910:														
352	30.8	9.9	78	42	120	67.9	53.9	4.0	62.3	35.2	57.0	2,760	1,720	16.9
353	40.6	12.5	78	43	121	68.9	56.7	3.7	......	......	......	......	......	15.0
354	28.3	9.4	78	43	121	66.8	55.9	3.5	......	......	......	......	......	14.6
365	27.2	7.9	78	43	121	70.9	51.8	3.7	63.1	34.4	49.8	3,250	2,049	17.6
367	96.6	19.8	86	36	122	79.5	85.3	5.0	51.4	25.3	48.1	2,199	1,129	9.6
Average	44.7	11.9	79.6	41.4	121	70.8	60.7	3.9	58.9	31.6	51.6	2,736	1,632	14.7
1911:														
352	11.1	4.8	74	34	109	56.1	96.4	6.5	56.9	33.9	59.5	6,410	3,650	37.5
353	11.8	5.6	74	34	109	52.5	95.1	6.3	53.6	33.3	62.1	6,040	3,240	34.9
354	11.5	5.5	74	34	109	52.3	94.7	6.0	57.8	34.7	60.0	5,875	3,400	35.2
365	13.1	5.9	74	34	109	55.4	95.4	6.0	55.5	33.9	61.1	5,871	3,261	34.4
367	13.5	5.1	93	16	109	62.3	100.0	6.5	36.8	14.1	38.6	6,493	2,393	15.6
Average	12.2	5.4	77.8	30.4	109	55.7	96.3	6.3	52.1	30.0	56.3	6,138	3,315	31.5
1912:														
352	7.9	3.9	77	29	106	50.4	98.5	3.3	......	28.6	......	3,203	......	15.8
353	7.5	3.8	77	29	106	49.9	98.7	3.3	......	31.6	......	3,373	......	18.4
354	7.3	3.5	77	29	106	51.9	94.4	3.3	......	26.7	......	3,553	......	16.4
365	7.7	3.9	77	29	106	49.2	97.3	3.5	......	27.1	......	3,713	......	19.1
367	9.9	3.6	89	36	125	63.6	99.5	4.0	......	12.2	......	4,793	......	10.2
480	5.2	3.3	82	24	106	37.2	97.4	2.8	......	26.2	......	2,925	......	13.2
481	7.4	3.6	82	24	106	51.1	90.8	2.8	......	19.9	......	2,638	......	9.1
488	4.0	2.9	82	24	106	26.4	99.0	3.0	......	14.1	......	3,269	......	7.8
499	12.5	5.1	82	24	106	59.0	93.7	3.0	......	17.5	......	2,138	......	6.5
Average	7.7	3.7	80.5	27.5	108	48.7	96.6	3.2	......	22.8	......	3,289	......	12.9
1913:														
352	5.9	3.8	70	......	......	35.9	......	1.7	......	......	......	......	......	......
353	5.4	3.7	79	......	......	31.0	......	1.7	......	......	......	......	......	......
354	6.7	4.2	70	......	......	36.9	......	1.7	......	......	......	......	......	......
365	6.7	4.5	70	......	......	32.9	......	1.7	......	......	......	......	......	......
367	9.4	4.1	......	......	......	56.1	......	1.7	......	......	......	......	......	......
480	5.0	3.3	79	......	......	34.9	......	1.7	......	......	......	......	......	......
481	5.9	3.4	70	......	......	42.4	......	1.7	......	......	......	......	......	......
488	8.3	4.4	79	......	......	46.2	......	1.7	......	......	......	......	......	......
499	6.3	4.3	70	......	......	31.4	......	1.7	......	......	......	......	......	......
Average	6.6	4.0	73.3	......	......	38.6	......	1.7	......	......	......	......	......	......
1914:														
352	12.7	4.7	68	23	91	62.8	98.8	4.3	......	14.9	......	4,440	......	11.4
480	16.1	5.6	68	23	91	65.3	98.4	4.0	......	8.3	......	4,320	......	6.2
Average	14.4	5.2	68	23	91	64.0	98.6	4.1	......	11.6	......	4,380	......	8.8
1915:														
352	16.8	5.6	75	44	119	66.6	83.9	5.3	48.3	35.5	73.5	9,680	4,680	59.3
480	16.3	5.1	75	41	116	68.6	74.3	5.3	50.8	37.8	74.7	9,560	4,840	62.4
Average	16.6	5.4	75	43	118	67.6	79.1	5.3	49.5	36.6	74.1	9,620	4,760	61.8
1916:														
352	7.7	3.9	82	31	113	48.7	98.1	3.3	......	10.2	......	2,740	......	4.8
480	8.6	3.5	62	30	92	48.3	98.9	3.3	......	28.5	......	1,400	......	6.9
Average	8.1	3.7	72	31	102	48.5	98.5	3.3	......	19.3	......	2,070	......	5.9

The yields obtained from all lots in all years are shown in Table XI. The average acre yield of Alba milo in the seven years from 1910 to 1916, inclusive, was about 20 bushels, or nearly 3 bushels less than that of milo. In no year has the average yield of all lots of the Alba variety exceeded the average yield of all lots of standard milo. Likewise, the highest yielding Alba has never equaled the highest yielding milo. In 1915, the year of bumper yields, however, the average yield of the two lots of Alba equaled the average yield of the five lots of milo, being 61.8 and 61.4 bushels per acre, respectively. In short, Alba milo is almost identical with milo in all its adaptations, but so far is slightly below milo in yield. The annual and average yields of one strain are compared with those of the other milos and durras in Table XVIII.

TABLE XI.—*Annual and average acre yields of all lots of Alba, or White, milo grown at the Amarillo Cereal Field Station during periods of varying length in the seven years from 1910 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

C. I. No.	Annual yields (bushels).							Average yields.			
	1910	1911	1912	1913	1914	1915	1916	4 years, 1910 to 1913.	5 years, 1912 to 1916.	7 years, 1910 to 1916.	
								Bus.	*Bus.*	*Bus.*	*Cwt.*
352	16.9	37.5	15.8	0	11.4	59.3	4.8	17.5	18.3	20.8	12.0
353	15.0	34.9	18.4	0				17.1			
354	14.6	35.2	16.4	0				16.0			
365	17.6	34.4	19.1	0				17.8			
367	9.6	15.6	10.2	0				8.8			
480			13.2	0	6.2	62.4	6.9		17.5		
481			9.1	0							
488			7.8	0							

FETERITA.

Feterita[1] is a variety of the milo group introduced from the British-Egyptian Sudan. It is similar to milo in most of the characters of the stalks and leaves. In height it averages about 5 feet under Panhandle conditions, or about 1 foot taller than milo. The head or spike is more elongated, elliptical rather than ovate in outline, somewhat less compact than that of milo, and always erect. The seeds are a chalky white, or sometimes bluish white, rather than a yellowish white or pale buff. The seeds also are softer than those of milo, and hence more likely to decay in a cold, wet soil. A plat of feterita grown at Amarillo, Tex., in 1915, is shown in figure 7.

One importation was received in time to be included in the experiments in the spring of 1908, while a second was added in 1914. Only 12 plats have been grown, therefore, in the 9-year period. The results obtained are shown in Table XII.

The total length of the growing period of feterita has varied greatly in the nine years. The average is about 107 days. In general, the responses of feterita have been about the same as those of milo to the same conditions. The shortest period recorded is 93 days, in 1914, and the longest 122 days, in 1912, though the total duration in 1910, 1915, and 1916 was between 115 and 119 days. In 1910 the vegetative and ripening periods were both prolonged, while in the last two years only the ripening period was extended. The reasons for these facts have been already stated under "Milo" and "Dwarf milo" and need not be repeated here.

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[1] Vinall, H. N., and Ball, C. R. Feterita, a new variety of sorghum. *In* U. S. Dept. Agr., Bur. Plant Indus. Cir. 122, p. 25-32. 1913.

TABLE XII.—*Agronomic data for feterita grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

C. I. No. and year.	Row space.		Length of period.			Suckers.	Headed.	Height of plants.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
C. I. No. 182:	*Ins.*	*Ins.*	*Days.*	*Days.*	*Days.*	*Per ct.*	*Per ct.*	*Feet.*	*Per ct.*	*Per ct.*	*Per ct.*	*Lbs.*	*Lbs.*	*Bus.*
1908	10.0	4.4	71	31	102	56.0	......	6.5	......	......	......	......	......	40.2
1909	16.1	10.3	72	27	99	36.0	......	......	......	......	57.5	......	......	9.3
1910	37.3	9.3	80	36	116	75.1	100.0	5.5	73.6	33.3	45.2	2,570	1,891	14.7
1911	14.6	5.3	67	35	102	64.0	100.0	5.5	56.4	38.8	68.7	4,775	2,695	31.9
1912	12.2	4.3	76	46	122	64.5	85.9	4.3	63.5	37.5	59.0	3,780	2,403	24.5
1913	7.9	4.7	69	......	......	40.3	......	......	......	......	......	......	......	......
1914	11.8	4.9	60	29	89	58.3	63.6	4.5	......	23.7	......	4,600	......	18.5
1915	25.0	7.3	68	51	119	70.6	100.0	5.3	......	35.1	......	8,600	......	52.1
1916	8.2	4.2	67	46	113	48.6	48.8	3.0	......	31.8	......	2,640	......	14.5
C. I. No. 567:														
1914	9.9	4.0	80	17	97	59.2	24.7	4.0	......	10.6	......	4,000	......	7.3
1915	34.6	11.3	74	45	119	67.8	86.1	5.8	......	41.4	......	5,840	......	41.7
1916	7.7	3.8	79	37	116	50.5	23.6	3.5	......	16.4	......	3,540	......	10.0
Average:														
1914	10.8	4.4	70	23	93	58.7	44.3	4.3	......	17.6	......	4,300	......	12.9
1915	29.8	9.3	71	48	119	69.0	95.5	5.5	......	38.2	......	7,220	......	46.9
1916	7.9	4.0	73	42	115	49.5	36.2	3.3	......	24.1	......	3,090	......	12.2

The average drill-row space per plant and per stalk in feterita is somewhat longer than in the case of milo. This is due chiefly to the softer seed and consequent poorer germination under unfavorable conditions, such as the dry spring weather in 1910 and the wet weather in 1915. In these two years the plant space was 37.3 and 29.8 inches, respectively, the widest spacing recorded for any variety in any year. The closest was 7.9 inches in 1913 and 1916.

The stalk space has varied only about half as widely, owing to the very free tillering of feterita. It has been more difficult to assign the proper limits to the vegetative and fruiting periods of feterita than to those of any of the other commercial varieties. This is due to the more uneven stands obtained and the greater variation in the number and percentage of suckers produced. Under dry spring conditions even a thin stand of feterita may head at an average height of only 3 or 3.5 feet. Under the influence of subsequent rains it may continue to produce suckers for some weeks, and these in turn continue to produce heads and to ripen seed. This condition represents really not one crop but two or three crops in succession on the same plants. This also helps to explain some of the records of prolonged periods of growth or ripening.

There has been much popular approval of feterita as a supposedly more drought-resistant crop than either milo or Dwarf milo, based on its occasional production of small to fair yields where the milos have failed completely. In the observation of the writers this has been due to the thinner stands, which are normal with this variety. These give it an advantage over the milos in dry seasons, when tillering is largely inhibited. In only two years, 1909 and 1913, both years of drought, has the proportion of suckers dropped below 50 per cent, or one sucker to each original plant. In 1915 there were 69 per cent and in 1910, 75.1 per cent of suckers, or an average of three fruiting suckers to each main stalk. These percentages are somewhat larger than those of milo in both cases.

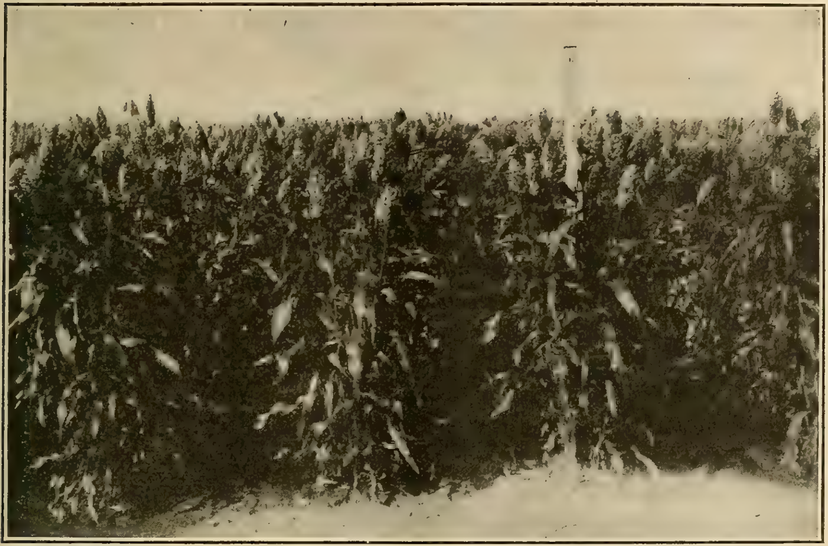

FIG. 7.—A plat of feterita, C. I. No. 182, at the Amarillo Cereal Field Station, September 28, 1915; yield, 55.5 bushels per acre.

The average acre yield of feterita (C. I. No. 182), in bushels of 58 pounds, has been 22.8 bushels in the 9-year period. This is approximately the same as the average acre yield of the best milo in the same period, but more than 4 bushels less than the average acre yield of the best Dwarf milo, as shown in Table XVIII. In two years, 1914 and 1916, however, this feterita has outyielded the best milo by quantities of 4 and 7 bushels, respectively. The lowest acre yield from this feterita was 9.3 bushels, in 1909, when the best milo made 16.5 bushels. The highest acre yield of this feterita was 52.1 bushels, in 1915, when the best lot of milo yielded 67.5 bushels. It is thus evident that feterita can scarcely compete with milo as a producer of grain; and milo, it should be remembered, is consistently outyielded by Dwarf milo.

WHITE DURRA.

The durra subgroup differs from the milos chiefly in the broader and more hairy glumes, not transversely wrinkled, and the flatter seeds. Two durra varieties were introduced into California in 1874 under the names "White Egyptian corn" and "Brown Egyptian corn," it being reported that they had come from Egypt. They have since become known as White durra and Brown durra, respectively. Like the milos, they differ from each other only in the color of the seeds.

The durras are low-growing plants with dry stems and few leaves. The heads are ovate or oval, rather compact, and commonly recurved or pendent. The broad seeds are lenticular in shape and much more flattened than in the case of milo or feterita. Very similar forms, no doubt the progenitors of these, are still found in cultivation in North Africa and in western Asia under the Arabic general name Dari. The forms of Turkestan are taller, with much more compact heads, and are known there as Dzhugara, a name probably from the same root as jowar, the name used in India for sorghum.

The white form of durra was rather extensively grown in the early days of dry farming in Kansas under the name Jerusalem corn. The brown form never has been commercially important. There are real objections to these varieties as farm crops. Among them are the recurved heads, the easily shattering seed, and the covering of hairs on the glumes. The first makes harvesting difficult, the second causes heavy loss of seed in wind or storm, as well as in harvest, and the third is very irritating to workmen in thrashing. Careful selection has eliminated the pendent heads and Nos. 27 and 81 have heads completely erect The shattering habit and hairy glumes have not yielded to simple selection, and none of the many hybrids has been entirely satisfactory in other respects.

Nine different lots or races have been included in the experiments, seven being included at the start in 1908 and two having been added since. In the last three years all but one have been discarded, and that one has been retained chiefly for illustration and comparison. Of the nine lots tested, Nos. 27 and 81 are selections from the ordinary White durra found in the United States, while No. 283 is an unselected lot of the same. No. 129 represents the Dzhugara from Turkestan. No. 244 is a form with less compact heads, called Edra, from Arabia. Nos. 247 and 248 are from India and not closely related to any of the others. The results of these experiments are shown in Table XIII.

TABLE XIII.—*Agronomic data for White durra grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

Year and C. I. No.	Row space.		Length of period.			Suckers.	Erect heads.	Height of plants.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
908:	*Ins.*	*Ins.*	*Days.*	*Days.*	*Days.*	*P. ct.*	*P. ct.*	*Feet.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Bus.*
27	7.1	4.2	68	28	96	40.8	......	5.0	......	......	......	......	......	31.6
81	8.6	5.3	63	30	93	38.3	......	6.0	......	......	......	......	......	35.7
129	......	......	75	......	......	......	......	......	......	......	......	......	......	......
244	8.7	4.7	78	34	112	45.9	......	......	......	......	......	......	......	......
247	......	......	77	......	......	......	......	6.0	......	......	......	......	......	......
248	11.8	5.6	77	34	111	52.5	......	5.0	......	......	......	......	......	32.7
283	......	......	67	28	95	......	......	......	......	......	......	......	......	......
Average	9.0	4.9	72	31	101	44.4	......	5.5	......	......	......	......	......	33.3
909:														
27	11.3	11.1	64	31	95	1.7	......	......	......	......	50.4	......	......	12.4
81	12.9	11.8	64	31	95	8.5	......	......	......	......	41.1	......	......	7.7
244	13.2	8.9	77	24	101	33.3	......	......	......	......	66.9	......	......	21.2
248	11.9	9.3	93	33	126	21.8	......	......	......	......	63.0	......	......	7.0
Average	12.3	10.3	74.5	29.7	104	16.3	......	......	......	......	55.3	......	......	12.1
910:														
27	14.8	14.8	70	26	96	0	100.0	5.0	64.5	34.0	52.7	1,993	1,286	11.7
81	12.8	8.1	59	38	97	36.7	100.0	5.0	61.8	31.0	50.2	1,866	1,154	10.0
244	24.7	11.4	78	38	116	53.8	75.1	6.0	......	......	......	......	......	8.8
248	47.9	15.0	95	32	127	68.6	47.9	4.5	......	......	......	......	......	7.8
373	34.4	22.3	70	51	121	35.2	41.8	3.7	......	......	......	......	......	......
Average	26.9	14.3	74	37	111	38.8	72.9	4.8	63.1	32.5	51.4	1,929	1,224	9.6
911:														
27	8.3	7.9	64	38	102	5.1	100.0	6.5	59.8	39.8	66.5	4,582	2,742	31.5
81	12.8	10.0	64	38	102	22.1	100.0	6.0	44.7	27.6	61.8	5,539	2,479	26.4
Average	10.5	8.9	64	38	102	13.6	100.0	6.2	52.2	33.7	64.1	5,060	2,610	28.9
912:														
27	2.7	2.7	71	33	104	......	95.2	4.0	47.4	24.0	50.7	3,440	1,630	14.3
81	4.7	4.5	71	33	104	5.0	94.6	4.3	65.8	41.1	62.5	3,420	2,252	24.3
434	5.2	5.2	76	28	104	......	84.7	3.5	......	......	......	3,163	......	13.7
Average	4.2	4.1	73	31	104	1.6	91.5	3.9	56.6	32.5	56.6	3,341	1,941	17.4
913:														
27	5.1	4.7	63	......	......	8.5	......	7.0	......	......	......	......	......	......
81	4.4	3.9	69	......	......	9.8	......	7.0	......	......	......	......	......	......
434	4.8	4.3	69	......	......	9.9	......	7.0	......	......	......	......	......	......
Average	4.7	4.3	67	......	......	9.4	......	7.0	......	......	......	......	......	......
914:														
81	7.9	6.3	58	31	89	20.5	98.9	5.3	......	44.8	......	2,900	......	22.4
915:														
81	11.7	7.5	65	43	108	34.0	97.2	5.5	......	44.9	......	4,760	......	36.9
916:														
81	10.1	8.2	73	42	115	19.1	61.4	3.3	......	28.8	......	900	......	4.5

It seems unnecessary to consider the White durras at any length, ecause none of them are of commercial importance. The following bservations relate exclusively to the common American form, repesented by Nos. 27 and 81, which is the only type having promise. t will be noted that this form is very early in maturing. The hortest growing period was 89 days, in 1914, and the longest 115 days, in the abnormally dry season of 1916. The average duration in normal seasons is about 95 days.

Germination, and consequent plant space, has been more uniform in this durra than in any of the milo varieties. In the very dry spring of 1910, stands of one plant every 12.8 and 14.8 inches, respectively, were obtained from the two lots. In the wet spring of 1915, when the milos germinated to rather poor stands, the one selection of White durra grown had a plant space of only 11.7 inches. The most striking physiological difference between the White durra and the milos is in relation to tillering. In some cases, as No. 27 in 1910 and 1912, absolutely no suckers were produced. In 1915, the very wet year, No. 81 produced only 34 per cent of suckers in the total stalks.

In height these selections exceed milo and White milo to a small extent. The average height is about 5 or 5.5 feet and the variation was from 4 feet in 1912 to 7 feet in 1913.

In yield these White durra selections fall below milo and feterita. The average acre yields of the two in the first six years, when both were grown, are 16.9 and 17.3 bushels, respectively, as shown in Table XIII. The average acre yield of No. 81 in the 9-year period was only 18.7 bushels. In 1915, the year of bumper yields, its record was only 36.9 bushels, about 1 bushel more than it yielded in 1908 and about 30 bushels less than that of the best milo. The yields of this selection are compared with those of other milos and durras in Table XVIII.

BUFF DURRA.

Under Buff durra are grouped, for convenience, several diverse varieties. None has been found to have any economic importance in the Panhandle.

Nos. 104 and 374 are the domestic Brown durra, which is the brown-seeded counterpart of White durra. No. 101 is a similar plant from North Africa. No. 183 is the Durra Safra or Yellow durra from Egypt, more truly a milo. No. 389 is a brown-seeded Dzhugara from Turkestan. Nos. 246, 249, and 250 are from India. Nos. 371, 372, and 376 are lots obtained from shiploads of chicken feed brought in ballast from Liverpool, England, but probably originating in India.

It is evident from the data in Table XIV that the performance of these varieties was so poor as to warrant discarding the entire lot at the end of 1913. No. 246, Dagdi Jowar, from India, seemed to be the most promising of all, but its average annual acre yield in the 6-year period was only 14 bushels. Most of the varieties were both tall in stature and late in maturing.

TABLE XIV.—*Agronomic data for Buff durra grown at the Amarillo Cereal Field Station during the 6-year period from 1908 to 1913, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

Year and C. I. No.	Row space.		Length of period.			Suckers.	Erect heads.	Height of plants.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
	Ins.	*Ins.*	*Days.*	*Days.*	*Days.*	*P. ct.*	*P. ct.*	*Feet.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Bus.*
1908:														
101	......	......	67	29	96	......	......	......	......	......	......	......	......	......
104	......	......	76	29	105	......	......	......	......	......	......	......	......	......
183	......	......	68	31	99	......	......	7.0	......	......	......	......	......	......
246	12.6	7.0	78	29	107	44.4	......	5.0	......	......	......	......	......	32.0
249	9.4	5.1	77	31	108	45.7	......	6.0	......	......	......	......	......	......
250	10.5	5.7	82	33	115	45.7	......	6.0	......	......	......	......	......	35.8
Average.	10.8	5.9	74.6	30.3	105	45.2	......	6.0	......	......	......	......	......	33.9
1909:														
183	15.3	14.9	72	......	......	2.6	......			......	47.8	......	......	7.8
246	13.8	10.7	83	......	......	22.4	......	......	......	......	51.9	......	......	9.8
Average.	14.5	12.8	77.5	......	......	12.5	......	......	......	......	49.8	......	......	8.8
1910:														
183	50.1	41.9	78	49	127	16.4	84.5	5.7	......	......	......	......	......	8.6
246	76.5	32.3	124	22	146	57.8	98.5	5.5	......	......	......	......	......	5.8
250	48.0	20.3	88	36	124	57.7	88.6	5.0	......	......	......	......	......	......
374	37.7	17.6	66	55	121	53.3	39.0	3.5	......	......	......	......	......	......
389	198.0	176.0	......	33	115	......	......	6.0	......	......	......	......	......	......
371	......	......	......	......	......	......	......	2.0	......	......	......	......	......	......
372	......	......	......	......	......	......	......	12.0	......	......	......	......	......	......
376	......	......	......	......	......	......	......	2.0	......	......	......	......	......	......
Average.	82.0	57.6	89	39	126	46.3	77.6	8.2	......	......	......	......	......	7.2
1911:														
183	18.6	18.1	72	46	118	2.7	100.0	7.5	57.3	34.5	60.2	4,310	2,460	25.7
246	9.7	6.7	93	25	118	30.9	100.0	5.8	35.4	16.0	45.1	6,875	2,435	19.0
Average.	13.6	12.4	82.5	35.5	118	16.8	100.0	6.6	46.3	25.2	52.6	5,592	2,447	22.3
1912:														
183	8.0	7.9	86	37	123	1.2	95.3	5.5	48.8	14.9	30.5	4,380	2,140	11.3
246	20.0	7.7	90	38	128	61.5	96.8	5.0	46.1	19.8	43.0	5,200	2,398	17.6
Average.	14.0	7.8	88	37.5	125.5	31.3	96.0	5.2	47.4	17.3	36.7	4,790	2,269	14.4
1913:														
183	7.2	7.1	79	......	......	1.0	......	2.5	......	......	......	......	......	......
246	5.2	4.6	......	......	......	12.0	......	2.5	......	......	......	......	......	......
Average.	6.2	5.8	79	......	......	6.5	......	2.5	......	......	......	......	......	......

MILO HYBRIDS.

The four selections considered under this head are derived from field hybrids of milo. Nos. 199 and 200 are selections made at the field station at Channing, Tex., in 1906. The first is from a supposed hybrid between Blackhull kafir and milo, while the parentage of the second is supposed to be Sumac sorgo and milo. Nos. 238 and 239 were chance hybrids of uncertain parentage found at the Amarillo Cereal Field Station in 1907. Selections were made only of forms having heads and kernels like those of milo in shape, but with the heads strictly erect. Since most field hybrids are tall, only the lowest were selected.

All four selections were grown in 1908. All were omitted in 1909 but reinstated in 1910. The number was decreased thereafter by the elimination of the least promising until only two remained in 1914, after which these also were discarded. In spite of continued selection, none of them showed any positive value either in productiveness, earliness, or dwarfness. The results obtained in the six years are shown in Table XV.

TABLE XV.—*Agronomic data for milo hybrids grown at the Amarillo Cereal Field Station during the 7-year period from 1908 to 1914, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

Year and C. I. No.	Row space.		Length of period.			Suckers.	Headed.	Height of plants.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
1908:	*Ins.*	*Ins.*	*Days.*	*Days.*	*Days.*	*P. ct.*	*P. ct.*	*Feet.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Bus.*
199	9.7	6.1	83	30	113	37.1	......	6.0	......	......	......	......	......	......
200	......	......	78	31	109	......	......	6.0	......	......	......	......	......	......
238	......	......	81	28	109	......	......	6.0	......	......	......	......	......	......
239	......	......	78	30	108	......	......	......	......	......	......	......	......	......
Average.	9.7	6.1	80	29.7	109.7	37.1	......	6.0	......	......	......	......	......	......
1910:														
199–24	22.8	11.3	101	26	127	50.4	61.8	4.5	......	......	......	......	......	8.5
238	34.4	14.2	*a* 76	45	121	58.7	42.2	4.7	......	......	......	......	......	......
238	32.8	15.4	95	27	122	52.9	92.9	5.2	......	......	......	......	......	12.3
238	41.4	18.2	*a* 73	46	119	56.0	87.4	5.5	......	......	......	......	......	8.0
Average.	32.8	14.8	86.2	36	122	54.5	71.1	4.9	......	......	......	......	......	9.6
1911:														
199–24	11.2	9.2	78	40	118	17.4	......	4.3	44.3	22.2	50.9	5,355	2,375	20.9
238	19.5	11.8	84	34	118	39.4	......	6.3	36.5	23.2	63.5	6,115	2,235	24.5
238	18.0	10.0	84	34	118	44.5	......	6.5	33.3	19.4	58.3	6,152	2,052	20.7
Average.	16.2	15.2	82	36	118	33.4	......	5.7	38.0	21.6	57.5	5,540	2,220	22.0
1912:														
199–24	10.7	7.0	90	42	132	36.1	84.9	4.5	35.6	14.9	41.8	6,780	2,415	17.4
238	8.0	5.0	90	45	135	33.9	74.5	4.0	30.6	18.3	45.1	5,920	2,413	18.8
238	11.2	5.7	90	45	135	48.9	72.2	4.5	40.4	22.3	55.1	5,420	2,192	20.8
Average.	9.9	5.9	90	44	134	39.6	77.2	4.3	35.5	18.5	47.3	6,040	2,340	19.0
1913:														
199–24	4.8	4.1	77	......	......	15.4	......	2.5	......	......	......	......	......	......
238	5.2	3.8	72	......	......	28.1	......	2.5	......	......	......	......	......	......
238	12.5	6.9	85	......	......	45.2	......	2.5	......	......	......	......	......	......
Average.	7.5	4.9	78	......	......	29.5	......	2.5	......	......	......	......	......	......
1914:														
199–24	8.7	6.3	85	25	110	28.1	40.2	3.5	12.8	7.7	......	5,140	660	6.9
238	13.0	6.4	80	27	107	50.7	23.4	4.0	9.3	5.3	......	4,520	420	4.1
Average.	10.9	6.5	82.5	26	108.5	39.4	31.8	3.8	11.0	6.5	......	4,830	540	5.5

[a] First and only heads.

DURRA-KAFIR HYBRIDS.

Only five separate hybrids are represented in the 18 selections contained in Table XVI. The remainder are varying forms selected from No. 198. Of the five, No. 141 is a hybrid called "Davis corn" found growing locally in Oklahoma and probably a cross between

Blackhull kafir and White durra. It was discarded after the season of 1912. No. 198 was a field hybrid, supposedly between Blackhull kafir and White durra, which occurred at the Channing Field Station in 1906. Among the various forms appearing in the second generation were many that seemed very promising. They appeared to combine the desirable earliness and low stature of the durra with head and seed characters more like those of kafir. Selections of these were made, and a number of them have been continued until the present time.

TABLE XVI.—*Agronomic data for durra-kafir hybrids grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

Year and C. I. No.	Row space.		Length of period.			Suckers.	Headed.	Height of plant.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
1908:	*Ins.*	*Ins.*	*Days.*	*Days.*	*Days.*	*P. ct.*	*P. ct.*	*Feet.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Bus.*
141	11.9	6.6	85	42	127	36.9	......	6.0	......	......	......	......	......	......
198-1	9.1	5.7	76	26	102	37.3	......	4.5	......	......	......	......	......	......
198-3	......	......	76	23	99	......	......	4.6	......	......	......	......	......	......
198-7	10.3	5.4	75	25	100	47.5	......	4.5	......	......	......	......	......	41.0
198-8	......	......	67	30	97	......	......	......	......	......	......	......	......	......
198-9	......	......	75	32	107	......	......	5.0	......	......	......	......	......	......
198-11	9.8	6.4	76	26	102	34.7	......	4.5	......	......	......	......	......	34.5
198-12	9.4	5.4	80	23	103	42.5	......	4.5	......	......	......	......	......	34 5
198-15	8.6	6.3	67	31	98	26.7	......	4.5	......	......	......	......	......	27.4
198-16	......	......	83	34	117	......	......	3.5	......	......	......	......	......	......
198-18	......	......	78	27	105	......	......	4.5	......	......	......	......	......	......
198-19	......	......	78	24	102	......	......	4.5	......	......	......	......	......	......
198-20	......	......	76	25	101	......	......	3.5	......	......	......	......	......	......
237	8.9	6.8	78	24	102	23.6	......	5.5	......	......	......	......	......	24.0
240	8.0	4.4	67	31	98	45.0	......	4.0	......	......	......	......	......	35.7
245	......	......	78	30	108	......	......	......	......	......	......	......	......	......
Average	9.5	5.8	75.9	28.3	104.2	36.7	......	4.5	......	......	......	......	......	32.8
1909:														
198-1-1	13.8	9.4	75	......	......	31.8	......	......	......	......	......	......	......	1.2
198-7-3	15.5	9.2	78	......	......	40.6	......	......	......	......	......	......	......	2.8
198-11-1	19.2	12.9	76	......	......	32.5	......	......	......	......	......	......	......	6.7
198-12-1 and 2	14.7	9.9	73	......	......	32.6	......	......	......	......	......	......	......	3.1
198-12-4	14.9	9.7	72	......	......	34.9	......	......	......	......	......	......	......	3.2
198-15-3	14.1	13.3	69	......	......	5.6	......	......	......	......	......	......	......	7.8
198-19-1 *a*	13.4	11.4	74	......	......	14.9	......	......	......	......	......	......	......	3.5
198-19-1 *b*	16.3	11.9	71	......	......	26.9	......	......	......	......	......	......	......	5.6
237-1	......	......	74	......	......	......	......	......	......	......	......	......	......	......
240	14.2	10.1	71	......	......	28.8	......	......	......	......	......	......	......	......
Average	15.2	10.9	73.3	......	......	27.9	......	......	......	......	......	......	......	4.2
1910 (black glumes):														
141-1-2-5	20.3	11.1	104	37	141	45.5	46.2	4.2	......	......	......	......	......	......
141-4-1-6	28.8	14.5	[a] 88	37	125	40.4	45.0	4.2	......	......	......	......	......	......
141-4-5-6	31.7	15.2	[a] 88	23	111	51.9	51.0	4.2	......	......	......	......	......	......
141-4-6-10	33.4	14.0	[a] 88	33	121	57.3	51.1	4.2	......	......	......	......	......	......
198-1-1	42.8	13.5	78	33	111	66.2	83.0	4.0	......	......	......	......	......	7.4
198-7-3	32.2	13.1	78	33	111	59.5	76.3	4.2	......	......	......	......	......	9.1
198-11-1 and 2	30.5	15.1	78	33	111	50.6	78.3	3.7	......	......	......	......	......	7.9
198-12-1 and 2	32.2	14.5	75	36	111	54.9	68.6	4.0	......	......	......	......	......	8.1
198-12-4	25.1	11.3	78	33	111	55.1	76.3	3.2	......	......	......	......	......	7.1
198-15-3	28.4	21.8	70	36	106	23.4	94.5	3.5	......	......	......	......	......	5.4
198-19-1 and 2	26.2	11.5	78	33	111	56.1	74.2	4.0	......	......	......	......	......	9.0

[a] First and only heads.

TABLE XVI.—*Agronomic data for durra-kafir hybrids grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive*—Continued.

Year and C. I. No.	Row space.		Length of period.			Suckers.	Headed.	Height of plant.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
1910 (white glumes):	*Ins.*	*Ins.*	*Days.*	*Days.*	*Days.*	*P. ct.*	*P. ct.*	*Feet.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Bus.*
198-7-3	17.7	6.4	94	25	119	63.7	82.4	4.5	......	......	......	......	......	21.2
198-12-1 and 2	20.3	8.2	94	25	119	59.5	82.3	4.0	......	......	......	......	......	16.3
198-12-4	16.3	6.5	94	25	119	59.9	85.9	4.0	......	......	......	......	......	18.8
198-15-3	19.5	13.5	75	34	109	30.7	100.0	3.7	......	......	......	......	......	16.0
198-19-3	21.0	8.0	91	28	119	61.7	66.4	5.0	......	......	......	......	......	17.0
237	16.1	11.3	94	25	119	29.9	99.3	4.2	......	......	......	......	......	12.7
240	18.5	6.7	75	34	109	63.6	88.1	3.2	......	......	......	......	......	17.0
Average	25.6	12.0	84.4	31.3	115.7	51.6	74.9	4.0	......	......	......	......	......	12.3
1911 (black glumes):														
141-1-2-5	3.2	3.0	77	46	123	6.5	......	5.7	28.3	14.0	50.8	7,881	2,231	19.6
141-4-5-8	4.1	3.4	77	46	123	16.8	......	5.7	29.2	9.9	34.1	7,775	2,275	13.4
198-1-1-2	3.2	2.5	72	33	105	21.5	......	6.0	53.7	27.8	51.9	7,768	4,168	37.3
198-7-3	5.9	3.8	75	30	105	36.6	......	5.7	47.5	26.2	55.1	6,674	3,174	30.2
198-11-1	5.6	4.3	77	28	105	23.9	......	5.5	52.3	31.3	59.8	7,080	3,700	38.2
198-12-1	4.8	4.3	75	30	105	9.6	......	5.7	55.7	32.2	57.8	6,332	3,472	34.6
198-12-4	6.1	4.1	72	33	105	32.2	......	6.0	54.5	27.3	50.0	5,690	3,100	26.7
198-15-3	6.3	5.7	70	30	100	9.2	......	6.5	59.5	38.3	64.2	6,039	3,599	39.9
198-19-1	5.4	4.0	72	33	105	26.3	......	6.5	50.2	18.7	37.2	5,375	2,700	17.3
1911 (white glumes):														
198-7-3	5.4	3.4	74	33	107	37.4	......	6.0	43.8	22.2	50.4	7,397	3,247	28.2
198-12-4	4.8	3.8	74	33	107	19.3	......	5.7	58.3	32.5	55.6	7,355	4,295	41.2
198-15-3	5.2	5.0	72	30	102	3.9	......	6.3	48.3	30.4	63.0	6,485	3,135	34.1
198-19-3	3.7	3.2	74	33	107	12.5	......	7.5	56.1	31.3	40.0	6,780	3,810	26.3
237	5.3	4.3	79	46	125	17.9	......	6.3	23.2	7.6	33.4	12,355	2,845	16.4
240	3.5	2.5	68	34	102	29.3	......	5.7	64.2	37.7	58.7	7,088	4,555	46.1
240-6	4.2	3.9	62	36	98	5.5	......	4.5	42.0	40.7	96.8	4,312	1,812	30.3
Average	4.8	3.8	73.1	34.6	107.7	19.2	......	5.9	47.9	26.7	53.6	7,021	3,257	29.9
1912 (black glumes):														
141-1-2-5	6.4	5.0	89	40	129	22.1	5.6	4.0	3.0	2.6	57.7	3,713	113	1.7
141-4-5-8	6.1	4.5	93	36	129	25.3	1.4	3.7	.9	.5	56.6	3,230	30	.3
198-1-1-2	5.1	3.7	89	35	124	26.7	25.3	3.5	28.5	6.1	21.5	2,560	730	2.7
198-7-3	6.2	4.3	89	35	124	30.7	34.9	3.5	21.3	4.6	21.7	3,700	790	3.0
198-11-1	7.7	5.4	93	31	124	29.6	39.3	3.3	37.6	8.5	22.7	2,700	1,015	4.0
198-12-1	4.8	4.1	96	28	124	14.9	24.3	3.3	27.6	4.2	15.3	2,800	773	2.0
198-12-4-1	4.6	4.0	96	28	124	13.8	34.1	3.3	......	5.2	......	2,453	......	2.2
198-12-4-5	7.9	5.0	93	31	124	36.6	43.7	3.5	......	8.2	......	2,675	......	3.8
198-15-3	6.4	5.6	89	35	124	13.3	37.7	3.3	......	9.4	......	2,533	......	4.1
198-19-1	7.9	4.8	93	31	124	39.3	40.5	3.7	......	8.4	......	2,660	......	3.9
1912 (white glumes):														
198-7-3	4.7	3.9	89	35	124	17.8	47.7	3.5	......	11.7	......	2,960	......	6.0
198-12-4	3.9	3.4	89	17	106	12.0	37.9	3.3	......	8.8	......	3,030	......	4.6
198-15-3	9.9	7.8	78	34	112	20.6	68.0	3.5	......	21.3	......	3,146	......	11.6
198-19-3	5.2	4.0	89	35	124	22.6	63.9	4.5	......	15.3	......	3,595	......	9.5
237	7.2	5.5	96	28	124	23.6	38.5	3.3	......	7.1	......	2,655	......	3.3
240	4.5	3.5	89	35	124	23.6	33.9	3.3	......	11.1	......	2,630	......	5.0
240-6	4.1	3.8	81	30	111	7.8	74.5	2.3	......	32.3	......	3,003	......	11.5
Average	6.0	4.6	90	32	122	22.3	37.7	3.4	19.8	9.7	32.6	2,944	575	4.6
1913 (black glumes):														
198-7-3	9.7	5.2	73	......	......	46.1	......	2.0	......	......	......	......	......	......
198-11-1	10.3	6.7	82	......	......	35.0	......	2.0	......	......	......	......	......	......
198-12-1	7.9	6.0	82	......	......	24.7	......	2.0	......	......	......	......	......	......
198-12-4-5	10.2	6.4	80	......	......	38.0	......	2.0	......	......	......	......	......	......
198-15-3	12.2	9.6	73	......	......	21.5	......	2.0	......	......	......	......	......	......
1913 (white glumes):														
198-7-3	10.6	5.5	80	......	......	47.9	......	2.0	......	......	......	......	......	......
198-12-4	6.9	5.2	80	......	......	25.2	......	2.0	......	......	......	......	......	......
198-15-3	12.0	8.7	73	......	......	27.1	......	2.0	......	......	......	......	......	......
240	88.2	4.9	80	......	......	40.0	......	1.5	......	......	......	......	......	......
240-6	9.9	5.9	73	......	......	40.0	......	1.5	......	......	......	......	......	......
Average	9.8	6.4	77	......	......	34.5	......	1.9	......	......	......	......	......	......

TABLE XVI.—*Agronomic data for durra-kafir hybrids grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive*—Continued.

Year and C. I. No.	Row space.		Length of period.							Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.	Suckers.	Headed.	Height of plant.	Heads in crop.	Crop.	Heads.	Total crop.	Heads.	Seed.
1914 (black glumes):	Ins.	Ins.	Days.	Days.	Days.	P. ct.	P. ct.	Feet.	P. ct.	P. ct.	P. ct.	Lbs.	Lbs.	Bus.
198-7-3	10.6	6.1	66	31	97	42.2	58.7	4.0	......	20.2	......	4,640	......	16.2
198-15-3	11.2	10.2	66	31	97	9.0	83.3	3.5	......	30.9	......	3,880	......	20.7
Average	10.9	8.2	66	31	97	25.6	71.0	3.7	......	25.5	......	4,260	......	18.4
1914 (pale glumes):														
198-7-3	10.7	6.3	66	31	97	41.3	53.6	3.5	......	18.8	......	4,240	......	13.8
198-15-3	12.2	10.7	66	31	97	11.5	74.2	3.5	......	25.0	......	3,440	......	14.8
240	5.9	4.7	64	29	93	20.6	37.2	3.0	......	15.8	......	3,160	......	8.6
240-6	8.2	6.1	57	30	87	26.0	78.3	2.8	......	46.6	......	2,400	......	19.3
Average	9.2	6.9	63.2	30.2	93.5	24.8	60.8	3.2	......	26.5	......	3,310	......	11.6
1915 (black glumes):														
198-7-3	15.0	9.5	74	49	123	36.9	98.4	5.0	......	34.9	......	5,720	......	34.5
198-15-3	15.4	12.4	74	49	123	19.1	95.8	5.3	......	30.8	......	4,600	......	24.5
Average	15.2	10.9	74	49	123	28.0	97.1	5.2	......	32.8	......	5,160	......	29.5
1915 (pale glumes):														
198-7-3	11.3	6.9	72	51	123	39.0	100.0	5.5	......	25.7	......	6,333	......	28.1
198-15-3	8.9	8.4	61	47	108	5.5	100.0	5.3	......	19.8	......	5,240	......	17.9
240	13.3	6.6	74	49	123	50.0	98.9	4.5	......	33.7	......	5,040	......	29.3
240-6	8.3	6.6	64	54	118	20.2	100.0	4.0	......	52.5	......	4,000	......	36.2
Average	10.4	7.1	68	50	118	28.7	99.7	4.8	......	32.9	......	5,153	......	28.4
1916 (black glumes):														
198-7-3	13.9	8.8	83	23	106	36.9	61.8	2.8	......	19.4	......	2,160	......	7.2
198-15-3	29.0	25.0	78	37	115	13.9	55.5	2.8	......	21.9	......	640	......	2.4
Average	21.5	16.9	80	30	110	25.4	58.6	2.8	......	20.7	......	1,400	......	4.8
1916 (pale glumes):														
198-7-3	13.1	9.7	80	65	145	25.7	23.8	2.5	......	20.8	......	1,600	......	5.7
198-15-3	21.0	18.0	80	65	145	14.1	28.2	2.5	......	17.9	......	560	......	1.7
240	7.8	5.2	117	28	145	32.1	55.1	3.0	......	7.4	......	2,720	......	3.5
240-6	16.5	12.4	63	34	97	24.2	63.6	2.3	......	31.3	......	640	......	3.5
Average	14.6	11.3	85	48	133	24.0	42.7	2.6	......	19.3	......	1,355	......	3.6

Nos. 237 and 240 were field hybrids occurring at the Amarillo field station in 1907. Presumably these also were crosses between Blackhull kafir and White durra. No. 237 was discarded at the end of 1912, but two selections of No. 240 are still grown. No. 245 is supposed to be a cross between Edra (No. 244), a white durra from Arabia, and some other variety. It appeared at Channing in 1906, and the selection was finally discarded at the end of its first season in 1908.

The number of selections grown was increased from 16 in 1908 to 18 in 1910 and then decreased until only 6 have been tested in each of the last three years. These include selections from only 2 of the

5 originally under experiment. The total number of plats grown in the nine years has been 105. The results are shown in Tables XVI and XVII, and the best strains are compared with others of the milo-durra group in Table XVIII. Beginning in 1910, an attempt was made to isolate both black-glumed and white-glumed selections from some of the selections which were not homozygous for glume color.

From a study of the data in Table XVI it appears that the selections of 198, 237, and 240 are early in maturing and the selection No. 240–6 especially so. The average duration of the growing period lies between 100 and 110 days in fairly normal seasons. In 1914, when all varieties of grain sorghums matured quickly, No. 240–6 matured in 87 days, and none of the six selections required more than 97 days to mature. In 1915, when all grain sorghums were late, these selections required only 118 days on the average, or a little less time than milo.

The germination of these hybrid selections has been good, on the average. Only once in the nine years has the plant space exceeded 15 inches. In five of these years the plant space has averaged less than 10 inches and in one year less than 5 inches. In the very dry spring of 1910 the germination was poor and the average space was 25.6 inches. In 1915, however, with its very wet spring, the average spacing was only 10.4 and 15.2 inches for the two subgroups, respectively. These selections do not tiller as freely as their kafir parent, but a little more freely than the durra parent. Only once, in 1910, have half of the stalks been suckers and only three times have as many as 30 per cent been suckers. The lowest record is 19.2 per cent, in 1911. The average height has been 4 feet.

The yields of all varieties are given in Table XVI and the yields of the best strains or races in Table XVII. No fair comparison can be made by considering the average acre yield of all the selections in all the years, because these are widely varying hybrid forms instead of pure-line selections from a mass variety. It is necessary, therefore, to determine the average acre yield of each of such selections as have been grown throughout the 9-year period. There are only three of them, but there are two others that were separated from two of the original three after the experiment had run two years. There is still another, No. 240–6, which has been grown during the last six years.

As grown during 1908 and 1909, both black-glumed and white-glumed forms occurred in the selections of No. 198. In the autumn of 1909 selections were made for glume color, and in 1910 head rows of each color were sown. The yields recorded in 1908 and 1909 are from the mixed lots, and hence are identical in both sections of the table. The subsequent yields are those given by the different selections.

Table XVII.—*Annual and average acre yields of the best durra-kafir hybrids grown at the Amarillo Cereal Field Station during periods of varying length in the nine years from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

Selection and C. I. No.	Annual yields (bushels).									Average yields.			
	1908	1909	1910	1911	1912	1913	1914	1915	1916	5 years, 1909 to 1913.	6 years, 1908 to 1913.	9 years, 1908 to 1916.	
Black glumed:										*Bus.*	*Bus.*	*Bus.*	*Cwt.*
198–1–1	......	1.2	7.4	37.3	2.7	0	......	......	......	9.7	......	......	......
198–7–3	41.0	2.8	9.1	30.2	3.0	0	16.2	34.5	7.2	9.0	14.4	16.0	9.3
198–11	34.5	6.7	7.9	38.2	4.0	0	......	......	......	11.4	15.2	......	......
198–12	34.5	3.1	8.1	34.6	2.0	0	......	......	......	9.6	13.7	......	......
198–12–4	34.5	3.2	7.1	26.7	2.2	0	......	......	......	7.8	12.3	......	......
198–15–3	27.4	7.8	5.4	39.9	4.1	0	20.7	24.5	2.4	11.4	14.1	14.7	8.5
198–19	......	3.5	5.6	17.3	3.9	0	......	......	......	6.1	......	......	......
White glumed:													
198–7–3	41.0	2.8	21.2	28.2	6.0	0	13.8	28.1	5.7	11.6	16.5	16.3	9.5
198–12–4	34.5	3.2	18.8	41.2	4.6	0	......	......	......	13.6	17.1	......	......
198–15–3	27.4	7.8	16.0	34.1	11.6	0	14.8	17.9	1.7	13.9	16.2	14.6	8.5
198–19–3	......	3.5	17.0	26.3	9.5	0	......	......	......	11.3	......	......	......
237	24.0	4.1	12.7	16.4	3.3	0	......	......	......	7.3	10.1	......	......
240	35.7	4.2	17.0	46.1	5.0	0	8.6	29.3	3.5	14.5	18.0	16.6	9.6
240–6	35.7	4.2	17.0	30.3	11.5	0	19.3	36.2	3.5	12.6	16.5	17.5	10.2

The average yields of the two white-glumed selections, Nos. 198–7–3 and 198–15–3, during the 9-year period are 16.3 and 14.6 bushels, respectively. If the yields recorded for these two in 1908 and 1909 are taken as the yields of the two black-glumed selections in the same years, their average yields are 16.0 and 14.7 bushels, respectively. Although the annual yields of the members of these two pairs varied greatly, the 9-year average yields of the two selections bearing the same numbers but having different glume colors are seen to be practically identical. The 9-year average yield of selection No. 240 is 16.6 bushels per acre, almost exactly that of the selection No. 198–7–3, both black glumed and white glumed.

The 6-year average acre yield of selection No. 240–6 in the years 1911 to 1916, inclusive, was 16.8 bushels, while the average yield of No. 240 itself was only 15.6 bushels in the same six years. All these average yields are much lower than those of Dwarf milo, milo, White milo, or feterita, and somewhat lower than those of White durra, the average yield of which was 18.7 bushels per acre in the same period. The yields of the durra-kafir hybrids are very irregular, although their variations correspond in general with those in the yields of other groups. In 1911 the yield of the black-glumed No. 198–15–3 equaled that of the best milo, while No. 240 surpassed it by some 7 bushels. In 1914, an unfavorable year, four of the six surpassed the best milo in yield, but in 1915, a year of abundant rainfall, the best of these fell 31 bushels behind the best milo.

The relatively low average yields of these hybrids are due in part to their comparatively poor yields in 1915, when bumper yields were obtained from most varieties. This was due to a considerable extent to their location on a part of the farm exposed to the ravages of sparrows, by which much of the seed was destroyed. In 1908, a good year, their yields compared well with those of the other varieties. On the whole, however, their performance has been disappointing.

COMPARATIVE YIELDS OF THE MILOS AND DURRAS.

Table XVIII compares the annual and average yields of the leading varieties of the milo-durra group. The data cover 5 milos, 5 Dwarf milos, 1 lot each of Alba (White) milo, feterita, and White durra, and 6 durra-kafir hybrids, a total of 19 lots. Of these, 13 have been grown during all years and 6 during only the last seven years.

Among the six subgroups, Dwarf milo is seen to lead, with average acre yields of 26 or 27 bushels. The Standard milos and Alba milo and feterita come next, with acre yields varying from 20 to 23 bushels, in round numbers. Below them rank the White durra and durra-kafir hybrids. As noted previously, the average yields of the last named probably would have been higher if they had not been seriously attacked by sparrows in 1915, the year of very high crop yields.

TABLE XVIII.—*Annual and average acre yields of the leading varieties and races in each of the subgroups of the milo-durra group of grain sorghums grown at the Amarillo Cereal Field Station in all or most of the nine years from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

Variety and C. I. No.	Annual and average acre yield (bushels).										
	1908	1909	1910	1911	1912	1913	1914	1915	1916	7 years, 1910 to 1916.	9 years, 1908 to 1916.
Milo:											
77	......	......	19.0	28.2	32.1	0	8.3	56.2	6.6	21.5	......
223	37.4	16.5	18.8	24.4	23.6	0	12.8	64.8	7.6	21.7	22.9
232	30.4	3.6	9.8	30.1	33.0	0	10.7	60.0	6.6	21.5	20.5
234	43.2	5.8	18.2	33.3	23.3	0	14.8	58.6	6.9	22.2	22.7
235	......	......	18.9	39.3	11.9	0	8.4	67.6	7.2	21.9	......
Dwarf milo:											
149	[a] 42.6	[a] 12.4	[a] 20.8	[b] 36.8	[b] 13.3	0	30.0	74.1	7.6	26.1	26.4
236	......	......	18.6	38.1	11.2	0	31.0	62.7	6.9	24.1	......
332	[b] 39.5	[c] 14.3	[b] 18.5	37.4	24.0	0	30.0	70.3	9.7	27.2	27.1
347	......	......	18.2	38.9	19.1	0	27.1	72.4	10.3	26.6	......
359	......	......	20.0	37.3	34.6	0	16.2	68.3	8.6	26.4	......
Alba (White) milo:											
352	......	......	16.9	37.5	15.8	0	11.4	59.3	4.8	20.8	......
Feterita:											
182	40.2	9.3	14.7	31.9	24.5	0	18.5	52.1	14.5	22.3	22.8
White durra:											
81	35.7	7.7	10.0	26.4	24.3	0	22.4	36.9	4.5	17.8	18.7
Durra-kafir hybrids:											
Black glumed—											
198-7-3	41.0	2.8	9.1	30.2	3.0	0	16.2	34.5	7.2	14.3	16.0
198-5-3	27.4	7.8	5.4	39.9	4.1	0	20.7	24.5	2.4	13.9	14.7
White glumed—											
198-7-3	41.0	2.8	21.2	28.2	6.0	0	13.8	28.1	5.7	14.7	16.3
198-15-3	27.4	7.8	16.0	34.1	11.6	0	14.8	17.9	1.7	13.7	14.6
240	35.7	4.2	17.0	46.1	5.0	0	8.6	29.3	3.5	15.6	16.6
240-6	35.7	4.2	17.0	30.3	11.5	0	19.3	36.2	3.5	16.8	17.5

[a] Average of three plats.
[b] Average of two plats.
[c] Average of four plats.

THE KAFIR GROUP.

The kafir group already has been described and the leading varieties separated by means of a simple key. They are the largest plants and the latest in maturing of all the groups. While there is considerable difference in size and earliness between the different varieties of kafir, none of them is both as dwarf and as early as some variety in each of the other groups except, perhaps, shallu. In most of the southern Great Plains area, the kafirs were the first varieties to be extensively grown. In Texas the milos probably had the start of the kafirs, but in Oklahoma the widespread production of milo has been a more recent development, while in Kansas milo is scarcely yet a competitor of kafir. Heads of four varieties are shown in figure 8.

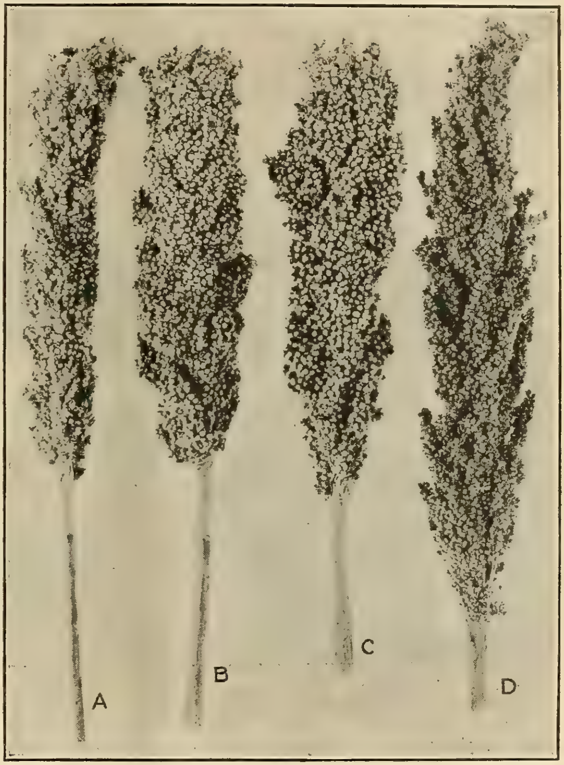

FIG. 8.—Heads of four varieties of kafir: *A*, White kafir; *B*, Guinea kafir (Guinea corn of the West Indies); *C*, Blackhull kafir; *D*, Red kafir. (About one-fifth natural size.)

The results obtained from the various kafirs are shown in Tables XIX to XXX, inclusive. It will be noted that, on the whole, the kafirs have made their good yields in years of normal rainfall and have yielded little in years of deficient precipitation. Since corn can not be grown at all under these conditions, it is no disparagement to the grain sorghums that some are less adapted than others. Each variety or subgroup of the kafirs is considered separately, and the results obtained are shown in separate tables.

BLACKHULL KAFIR.

The number of different lots and selections of Blackhull kafir which have been under experiment has decreased from 19 at the beginning, in 1908, to only 5 in 1916. They vary little among themselves, either in height, or earliness, or in producing power. A plat of Blackhull kafir is shown in figure 9.

Table XIX shows that in fairly normal seasons, such as those of 1908, 1911, and 1915, this variety requires about three months to reach the heading stage and nearly a month more to ripen, making the total duration of the growing period 115 to 120 days. The shortest period recorded is 107 days, for No. 207 in 1908, and the longest is 150 days, for three selections in 1915. Drought may shorten the vegetative period slightly by checking growth and so inducing heading. On the other hand, drought may greatly lengthen this period if it becomes so severe as to inhibit growth altogether until rains occur. This condition occurred in 1916, when the average duration of the vegetative period alone was 128 days and none of the five selections matured.

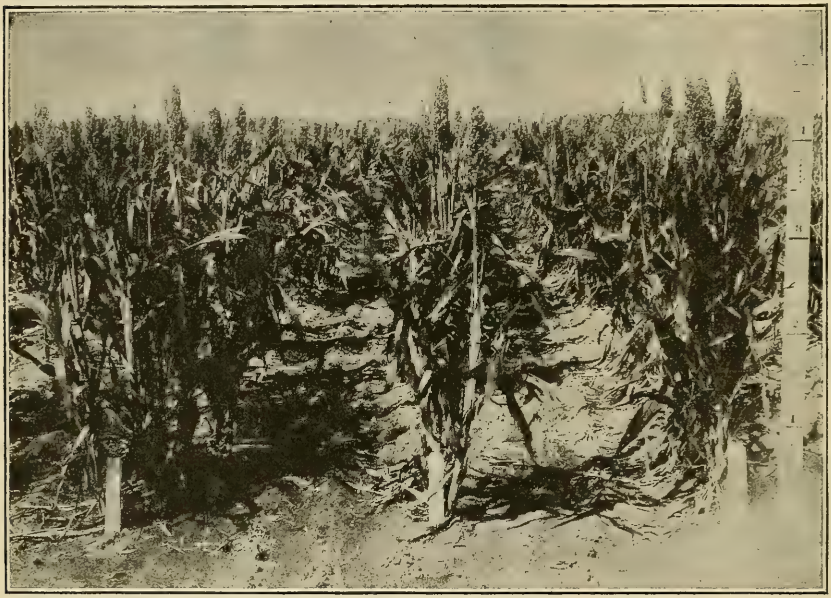

FIG. 9.—A plat of Blackhull kafir, C. I. No. 203, at the Amarillo Cereal Field Station, September 10, 1907.

The normal height of these varieties under Panhandle conditions is about 5 feet. Drought in early summer reduces this height materially. For instance, in 1910 to 1912, inclusive, the average height was between 4 and 4.6 feet. In 1914 and 1916 the average height fell below 4 feet, while in 1913 the crop was destroyed by drought at an average height of only 2 feet, mostly without producing any heads. In 1915, when the total precipitation was much above normal and the highest yields yet recorded were obtained, the average height was only 5.1 feet. This was due, however, to a somewhat reduced rainfall in May and June, while growth was being made, and superabundant moisture thereafter while the grain was being formed.

TABLE XIX.—*Agronomic data for Blackhull kafir grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 60 pounds.]

Year and C. I. No.	Row space.		Length of period.			Suckers.	Headed.	Height of plants.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
1908:	*Ins.*	*Ins.*	*Days.*	*Days.*	*Days.*	*Per ct.*	*Per ct.*	*Feet.*	*Per ct.*	*Per ct.*	*Per ct.*	*Lbs.*	*Lbs.*	*Bus.*
71	11.5	7.2	91	24	115	37.3	......	5.5	......	......	......	......	......	42.2
204-2	12.0	8.7	82	30	112	27.5	......	5.5	......	......	......	......	......	31.4
204-5	......	......	82	30	112	......	......	5.5	......	......	......	......	......	......
205-5	12.8	7.8	84	28	112	39.0	......	5.5	......	......	......	......	......	28.6
205-8	......	......	84	28	112	......	......	5.5	......	......	......	......	......	......
206	13.5	8.9	84	28	112	34.0	......	5.5	......	......	......	......	......	27.2
207	8.0	5.9	76	31	107	26.2	......	5.5	......	......	......	......	......	32.6
209-9	......	......	90	28	118	......	......	6.0	......	......	......	......	......	......
210	14.2	8.8	90	30	120	38.0	......	6.0	......	......	......	......	......	34.2
333	12.2	8.0	90	27	117	34.4	......	5.5	......	......	......	......	......	41.7
334	......	......	90	27	117	......	......	5.5	......	......	......	......	......	......
335	11.8	8.5	90	28	118	27.9	......	5.5	......	......	......	......	......	37.0
336	12.5	8.1	92	26	118	35.2	......	5.5	......	......	......	......	......	27.2
337	12.3	7.6	92	24	116	38.2	......	5.5	......	......	......	......	......	38.3
338	12.8	8.5	91	26	117	33.6	......	5.5	......	......	......	......	......	30.7
339	12.1	7.7	91	26	117	36.3	......	5.5	......	......	......	......	......	34.6
341	11.3	7.0	91	24	115	38.0	......	5.5	......	......	......	......	......	33.3
31	......	......	91	27	118	......	......	5.5	......	......	......	......	......	......
33	......	......	88	24	112	......	......	5.5	......	......	......	......	......	......
Average	12.0	7.8	87.8	27.1	115	34.2	......	5.6	......	......	......	......	......	33.8
1909:														
71	11.8	9.7	98	......	......	17.8	......	......	......	......	......	......	......	3.5
71	12.1	10.4	97	......	......	14.0	......	......	......	......	......	......	......	3.5
204-5	12.5	10.5	89	......	......	16.0	......	......	......	......	......	......	......	10.9
205	12.0	9.9	89	......	......	17.5	......	......	......	......	......	......	......	5.6
210	12.0	10.1	97	......	......	15.8	......	......	......	......	......	......	......	4.3
333	12.0	10.6	96	......	......	11.7	......	......	......	......	......	......	......	3.4
334	11.6	10.2	95	......	......	12.0	......	......	......	......	......	......	......	4.9
335	12.9	12.1	87	......	......	6.2	......	......	......	......	......	......	......	10.7
337	13.0	11.1	91	......	......	14.6	......	......	......	......	......	......	......	7.7
338	14.0	12.2	92	......	......	12.8	......	......	......	......	......	......	......	5.2
339	13.3	11.5	94	......	......	13.5	......	......	......	......	......	......	......	3.9
341	11.9	10.1	94	......	......	15.1	......	......	......	......	......	......	......	7.0
Average	12.4	10.7	92.4	......	......	13.9	......	......	......	......	......	......	......	5.9
1910:														
71	19.3	9.1	[a]91	39	130	53.0	......	4.0	......	......	......	......	......	1.0
185	17.6	9.3	[a]81	43	124	47.0	......	4.0	......	......	......	......	......	1.4
204	19.7	11.3	107	36	143	42.8	......	4.2	13.1	7.7	58.6	4,332	567	5.5
205	20.7	10.0	[a]76	48	124	51.7	......	4.2	10.4	5.7	54.9	4,150	433	4.0
207	21.9	11.4	[a]81	43	124	48.2	......	4.2	12.1	7.0	57.8	3,761	456	4.4
210	22.3	11.5	[a]91	38	129	48.6	......	4.2	......	......	......	......	......	1.6
242	19.7	10.2	[a]90	38	128	48.3	......	4.0	......	......	......	......	......	2.1
330	48.0	19.6	[a]93	36	129	59.3	......	4.0	......	......	......	......	......	1.5
333	19.2	10.3	[a]91	39	130	46.8	......	4.0	......	......	......	......	......	2.6
335	22.5	12.7	[a]91	35	126	43.4	......	4.0	......	......	......	......	......	4.8
337	29.2	12.6	[a]91	38	129	56.8	......	4.0	......	......	......	......	......	3.5
338	23.2	11.1	[a]91	39	130	52.3	......	4.0	......	......	......	......	......	2.6
339	27.9	12.3	[a]91	39	130	56.0	......	4.0	......	......	......	......	......	2.5
341	21.3	9.7	[a]90	33	123	54.4	......	4.0	......	......	......	......	......	2.5
355	24.0	10.7	[a]90	39	129	55.4	......	4.0	......	......	......	......	......	4.3
Average	23.7	11.4	89.6	38.8	128.5	50.9	......	4.1	......	......	......	......	......	2.9
1911:														
71	8.3	4.8	89	35	124	42.6	......	4.5	34.0	19.8	58.1	8,839	2,739	26.5
185	8.5	4.8	96	28	124	43.2	......	4.5	25.5	12.1	47.3	8,379	2,139	16.9
204	6.5	4.4	87	37	124	32.4	......	5.0	29.7	14.7	49.4	7,744	2,304	19.0
205	6.0	4.1	89	35	124	31.5	......	5.0	31.8	15.2	47.8	7,949	2,529	20.2
207	6.9	4.7	89	35	124	31.5	......	5.0	27.5	11.7	40.3	5,800	1,695	11.4
210	8.8	4.8	96	28	124	45.5	......	4.5	28.1	14.0	49.8	7,932	2,232	18.6
242	6.5	3.8	96	28	124	41.2	......	4.5	21.5	7.8	36.5	8,901	1,921	11.7
330	5.6	3.5	96	28	124	37.6	......	4.5	17.9	6.9	38.5	9,291	1,671	12.4
333	5.2	3.6	95	30	125	31.9	......	4.5	18.3	5.9	32.3	9,612	1,765	9.5
335	9.9	7.0	86	46	132	29.0	......	4.5	37.3	23.0	61.7	5,360	2,000	20.6
337	8.6	5.8	88	44	132	32.4	......	4.5	35.8	22.8	63.6	5,520	1,980	21.0
338	11.8	7.8	88	44	132	34.2	......	4.5	38.9	26.4	67.9	5,340	2,080	23.6

[a] First and only heads.

TABLE XIX.—*Agronomic data for Blackhull kafir grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive*—Continued.

Year and C. I. No.	Row space.		Length of period.			Suckers.	Headed.	Height of plants.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
1911—Contd.	*Ins.*	*Ins.*	*Days.*	*Days.*	*Days.*	*Per ct.*	*Per ct.*	*Feet.*	*Per ct.*	*Per ct.*	*Per ct.*	*Lbs.*	*Lbs.*	*Bus.*
339	12.1	7.1	88	44	132	41.1	......	4.5	32.2	21.4	63.0	5,995	1,975	21.4
341	13.2	7.3	86	46	132	44.6	......	4.5	41.2	27.6	66.9	5,179	2,139	23.9
355	11.3	7.0	88	44	132	39.1	......	4.5	36.9	24.8	67.2	5,839	2,159	24.2
Average	8.6	5.4	90.4	36.8	127	37.1	......	4.6	30.4	16.9	52.7	7,125	2,088	18.7
1912:														
71	10.5	5.5	[a]89	51	140	47.2	22.8	4.3	7.8	4.2	54.6	6,620	520	4.7
185	11.3	5.8	[a]89	51	140	48.7	23.0	4.3	8.0	4.4	54.8	6,200	500	4.6
204	9.9	5.2	96	39	135	46.7	53.3	4.3	29.2	11.0	38.0	4,980	[b]1,440	9.2
205	10.6	5.8	96	39	135	49.2	34.6	4.3	22.0	5.9	26.7	4,390	978	4.4
207	10.6	5.6	100	40	140	47.7	37.2	4.0	23.7	6.1	26.0	4,340	[b]1,033	4.5
210	9.7	5.7	[a]93	47	140	41.3	15.6	4.3	5.2	2.9	57.5	6,140	320	3.1
242	9.2	5.1	[a]89	51	140	44.7	14.6	4.3	4.0	2.3	58.5	6,818	278	2.7
330	9.3	5.6	[a]89	51	140	39.7	21.0	4.3	6.7	3.9	58.3	5,895	395	3.8
333	8.4	5.8	[a]89	51	140	30.9	11.7	4.3	4.8	2.6	55.0	5,720	280	2.6
335	7.6	5.5	[a]89	51	140	26.9	17.0	4.3	7.4	4.4	59.5	6,180	460	4.6
337	9.6	5.6	[a]89	51	140	41.4	26.0	4.3	7.6	4.3	56.8	6,580	500	4.7
338	9.9	5.5	[a]89	51	140	41.2	21.9	4.3	6.7	3.8	57.2	6,755	455	4.3
339	11.2	5.5	[a]89	51	140	51.0	15.2	4.3	4.3	2.1	51.1	6,395	275	2.3
341	14.3	6.6	99	40	139	53.7	47.6	4.0	18.7	10.7	57.4	3,815	715	6.8
355	12.4	6.3	[a]88	51	139	49.0	15.9	4.0	6.3	3.6	56.8	5,295	335	3.2
Average	10.3	5.6	91.5	47.6	139.2	43.9	25.1	4.2	10.8	4.8	51.2	5,741	565	4.3
1913:														
71	7.1	4.8	......	......	......	31.8	......	2.0	......	......	......	......	......	......
185	8.5	5.8	......	......	......	32.0	......	2.0	......	......	......	......	......	......
204	6.4	4.5	85	......	......	29.6	......	2.0	......	......	......	......	......	......
205	6.9	4.4	85	......	......	33.5	......	2.0	......	......	......	......	......	......
207	7.5	5.0	85	......	......	32.5	......	2.0	......	......	......	......	......	......
210	8.3	5.5	......	......	......	34.3	......	2.0	......	......	......	......	......	......
242	8.8	5.9	......	......	......	32.9	......	2.0	......	......	......	......	......	......
330	6.5	4.2	......	......	......	36.2	......	2.0	......	......	......	......	......	......
333	8.4	5.4	......	......	......	35.4	......	2.0	......	......	......	......	......	......
335	9.0	6.2	......	......	......	34.5	......	2.0	......	......	......	......	......	......
337	7.8	5.1	......	......	......	35.2	......	2.0	......	......	......	......	......	......
338	8.1	5.2	......	......	......	35.8	......	2.0	......	......	......	......	......	......
339	16.1	9.2	......	......	......	43.0	......	2.0	......	......	......	......	......	......
341	5.8	4.4	......	......	......	25.0	......	2.0	......	......	......	......	......	......
355	6.9	4.9	......	......	......	28.8	......	2.0	......	......	......	......	......	......
502	9.5	5.9	......	......	......	37.9	......	2.0	......	......	......	......	......	......
Average	8.2	5.4	......	......	......	33.6	......	2.0	......	......	......	......	......	......
1914:														
71	10.8	8.4	82	36	118	24.2	60.4	4.0	30.6	16.5	......	5,100	1,560	14.0
204	6.9	6.1	82	29	111	11.7	53.3	3.8	......	12.5	......	5,120	......	10.7
207	9.3	6.9	82	29	111	25.6	56.5	3.8	......	12.7	......	4,720	......	10.0
335	9.5	7.9	82	36	118	16.5	51.2	4.0	26.0	14.5	......	4,680	1,220	11.3
337	12.2	8.0	82	36	118	34.4	46.7	4.0	22.5	12.6	......	4,440	1,000	9.3
341	8.1	5.1	87	31	118	36.6	28.6	3.8	13.9	7.9	......	4,020	560	5.3
Average	9.4	7.1	82.8	32.8	115.6	24.8	49.4	3.9	23.2	12.8	......	4,680	1,085	10.1
1915:														
71	10.3	6.6	91	59	150	35.7	94.3	5.3	42.2	31.2	73.0	12,320	5,200	64.0
204	10.2	8.6	87	49	136	15.7	92.4	5.0	38.6	29.6	76.7	7,760	3,000	38.3
207	15.1	8.6	87	54	141	43.1	93.5	5.0	42.1	30.0	71.3	7,120	3,000	35.7
335	10.2	6.9	91	59	150	33.0	97.0	5.0	45.3	32.6	72.3	11,460	5,200	62.7
337	10.2	5.3	94	56	150	48.3	82.0	5.3	42.0	31.2	74.4	10,280	5,160	64.0
341	17.3	8.7	87	52	139	49.6	98.9	5.3	53.5	39.4	73.7	7,100	3,800	46.7
Average	12.2	7.4	89.5	54.8	144	37.6	93.0	5.1	43.9	32.3	73.6	9,340	4,226	51.9
1916:														
71	15.1	10.0	128	Did not mature.		34.0	34.3	3.5	No yields.					
204	11.9	7.6	128			36.2	30.2	3.5						
207	13.5	8.9	128			34.3	28.4	3.5						
355	9.1	6.4	128			30.0	24.2	3.5						
337	14.1	8.5	128			39.5	50.8	4.3						
Average	12.7	8.3	128	......	......	34.8	33.6	3.7						

[a] First and only heads.

[b] Machine headed.

The stands obtained vary somewhat with the conditions at sowing time. Either a cold, wet spring or an extra dry soil may reduce germination and consequent stand. The distance between plants in the Blackhull kafir varied from about 8 inches in 1911 and 1913 to 9, 10, and 12 inches in all the other years except 1910, when dry soil reduced germination and so doubled the average plant space.

The average stalk space is governed by conditions occurring during the vegetative period and determining the formation of suckers. In general, about one-third of the total stalks are suckers, making a proportion of 2 main stalks to 1 sucker. In 1909 the spring drought reduced the percentage to about 14, while in 1910 the May rains combined with thin stand induced vegetative growth until half the stalks were suckers. Both these were years of drought which reduced the yields almost to the vanishing point. It will be noted that in the dry year, 1912, when the spring rains were sufficient to produce 44 per cent of suckers, only 25 per cent of all stalks were able to produce heads.

TABLE XX.—*Annual and average yields of standard Blackhull kafir, Sunrise kafir, Dawn (dwarf) kafir, and White kafir grown at the Amarillo Cereal Field Station during periods of varying length in the nine years from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 60 pounds.]

Variety and C. I. No.	Annual yields (bushels).									Average yields.				
	1908	1909	1910	1911	1912	1913	1914	1915	1916	4 years, 1910 to 1913.	6 years, 1908 to 1913.	8 years, 1909 to 1916.	9 years, 1908 to 1916.	
Standard:										*Bus.*	*Bus.*	*Bus.*	*Bus.*	*Cwt.*
71	42.2	3.5	1.0	26.5	4.7	0	14.0	64.0	0	8.1	13.0	14.2	17.3	10.4
185	......	......	1.4	16.9	4.6	0	......	......	......	5.7	......	......	......	......
204	31.4	10.9	5.5	19.0	9.2	0	10.7	38.3	0	8.4	12.7	11.7	13.9	8.3
205	28.6	5.6	4.0	20.2	4.4	0	......	......	......	7.2	10.5	......	......	......
206	27.2	......	......	......	......	......	......	......	......	......	......	......	......	......
207	32.6	6.3	4.4	11.4	4.5	0	10.0	35.7	0	5.1	9.9	9.0	11.7	7.0
210	34.2	4.3	1.6	18.6	3.1	0	......	......	......	5.8	10.3	......	......	......
242	......	......	2.1	11.7	2.7	0	......	......	......	4.1	......	......	......	......
330	......	......	1.5	12.4	3.8	0	......	......	......	4.4	......	......	......	......
333	41.7	4.2	2.6	9.5	2.6	0	......	......	......	3.7	10.1	......	......	......
335	37.0	10.7	4.8	20.6	4.6	0	11.3	62.7	0	7.5	13.0	14.3	16.9	10.1
336	27.2	......	......	......	......	......	......	......	......	......	......	......	......	......
337	38.3	7.7	3.5	21.0	4.7	0	9.3	64.0	0	7.3	12.5	13.8	16.5	9.9
338	30.7	5.2	2.6	23.6	4.3	0	......	......	......	7.6	11.1	......	......	......
339	34.6	3.9	2.5	21.4	2.3	0	......	......	......	6.6	10.8	......	......	......
341	33.3	7.0	2.5	23.9	6.8	0	5.3	46.7	0	8.3	12.3	11.5	13.9	......
355	......	......	4.3.	24.2	3.2	0	......	......	......	7.9	......	......	......	
Sunrise:														
472	......	10.8	7.6	21.4	8.0	0	10.4	56.0	9.3	9.3	......	15.4	......	......
Dawn:														
340	29.0	14.4	[a]9.3	[a]34.9	[a]9.6	0	14.7	53.3	3.7	13.5	16.2	17.5	18.8	11.3
White:														
342	......	8.7	10.1	26.3	16.5	0	14.7	......	......	13.2	......	......	......	......
370	......	......	8.8	23.7	13.5	0	14.3	37.3	4.0	11.5	......	......	......	......

[a] Average yield from three plats.

A study of the annual and average acre yields, as given in Table XX, is very interesting in the light of the summary of climatic conditions given previously. In two years, 1913 and 1916, absolutely no yields of grain were obtained. In three years the average yields were between 3 and 6 bushels per acre. In two years, 1911 and 1914, small yields, averaging 18.7 and 10.1 bushels, respectively, were produced. In 1908 there was a full yield, 33.8 bushels per acre, while in 1915 the very large average of 51.9 bushels was obtained. The average annual production in the entire 9-year period, based on a total of 109 plats grown, is only 12.3 bushels per acre. The highest average acre yield, in this period, is 17.3 bushels. Two other lots grown in all nine years yielded 16.9 and 16.5 bushels, respectively, while the average yield of five lots is 15.3 bushels.

The comparatively low returns given by the standard forms of Blackhull kafir led to efforts for improvement through breeding. The Early, or Sunrise, kafir, and the dwarf variety discussed next in order are two of the varieties resulting from the breeding operations. Both have yielded better in the years in which they have been grown than any of the older forms, as will be seen in Table XX and again in Table XXX, where the annual and average yields of all leading kafirs are summarized.

SUNRISE KAFIR.

The Sunrise, or Early, kafir (C. I. No. 472) was developed from a single head, which bore the selection number 30. It was selected in the autumn of 1906 by Mr. A. H. Leidigh, then superintendent of the Amarillo Cereal Field Station. The Dawn (dwarf) kafir (C. I. No. 340) has been developed from the same head, the exact origin of which is not known. Probably it was selected in one of the Blackhull kafir plats on the station at Amarillo, or at Channing, Tex., where the station was located previous to 1906, but it may have been found on some near-by farm.

Head No. 30 was used to sow a head row in 1907. The resulting plants were like ordinary Blackhull kafir in nearly all respects except earliness and stature. This row was heading on August 14, while none of the other selections headed until August 26, or 12 days later. In height, row 30 varied from 3.5 to 5 feet, while the other selections ranged from 4.5 to 5.5 or 6 feet. The heads were compact, but not completely exserted from the upper sheath. The glumes were black, and the kernels apparently were a little longer than those of ordinary kafir.

The earliness and variable stature, as also the scarcely exserted heads, indicate hybridization. Since the plants in other respects are so typically Blackhull kafir, the hybridization must have been between that variety and another having very similar characters. Among all the grain sorghums, only White kafir could impart earliness, dwarf stature, and shorter peduncles to Blackhull kafir without changing its other characters. It seems safe to conclude, therefore, that we have here the progeny of a chance hybrid between Blackhull kafir and White kafir.

Six heads were saved from this head row of selection No. 30. The seed from these heads was sown in 1908 in six head rows, numbered 30–1 to 30–6, inclusive. Later in the year Cereal Investigations No. 340 was given to the selection No. 30. Two of these six rows, Nos. 1 and 2, proved uniformly dwarf and early, and heads selected in row 1 have been the progenitors of the Dawn (dwarf) kafir hereafter considered. Rows 3 to 6 were all early, but heterozygous for height. Row 4 contained both tall and dwarf plants, but was most uniform in other respects. Heads were selected from the tall plants. Rows 3, 5, and 6 were discarded.

In 1909 five head rows were grown (C. I. No. 340–4–1 to 5). These all bred fairly true to the tall early type, though containing some dwarf stalks. Heads were selected from both tall stalks and dwarf stalks. Their records in the plats begin with this year.

In 1910, seed from heads taken from tall plants was sown in 10 head rows (C. I. No. 340–4Bt–1 to 10). The resulting plants were nearly all tall, though a few dwarfs appeared again. The average height was 5.3 feet. The tall and early selection being now fairly well fixed, it was given the distinct number C. I. No. 472, and later named Sunrise on account of its earliness. Ten head rows (C. I. No. 340–4Bd–1 to 10) also were sown with seed from the dwarf plants in No. 340–4 of 1909. The plants in these rows were all homozygous for dwarf stature and differed not at all from those grown from the seed of No. 340–1 or Dawn (dwarf) kafir.

Like all the other kafirs, this selection did not produce heads in 1913. In the other seven years the average duration of the vegetative period has been 88 days, of the fruiting period 36 days, and of the whole growing period 124 days. Blackhull kafir did not mature in 1916, and the record of Sunrise is not complete in 1909, so that comparison can be made only for the five years, 1910 to 1912, 1914, and 1915. In these five years the average duration of the three periods in Sunrise kafir was 85.6 days, 38.6 days, and 124.2 days, respectively. In Blackhull kafir the average duration of these periods in all selections was 88.8 days, 42.2 days, and 131.0 days, respectively. This shows an average shortening of the growing period by 7.5 days in favor of the Sunrise kafir, which is an item of much importance in districts where the season is fairly short and summer drought is of frequent occurrence.

The complete experimental data are found in Table XXI, a study of which shows that fairly good germination and good stands were obtained in all eight years. The closest spacing was one plant to each 4.7 inches, the widest was one plant to each 17 inches, and the average was one plant to each 9.2 inches in the 8-year period. In the very dry spring of 1910, when poor germination was recorded from nearly all varieties, the plant space in Sunrise kafir was 17 inches.

In the wet spring of 1915, however, when the average plant space in all selections of standard Blackhull kafir was 23.7 inches, the space in Sunrise kafir was only 10.2 inches per plant.

TABLE XXI.—*Agronomic data for Sunrise kafir (C. I. No. 472), grown at the Amarillo Cereal Field Station during the 8-year period from 1909 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 60 pounds.]

Year.	Row space.		Length of period.			Suckers.	Headed.	Height of plants.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
	Ins.	*Ins.*	*Days.*	*Days.*	*Days.*	*P. ct.*	*P. ct.*	*Feet.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Bus.*
1909	12.3	10.6	80	......	......	13.8	66.6	......	......	......	65.5	......	......	10.8
1910	17.0	6.6	90	37	127	61.4	49.4	5.3	26.5	10.1	38.6	4,485	1,178	7.6
1911	4.7	3.0	82	41	123	35.8	......	6.3	31.1	14.6	47.1	8,716	2,716	21.4
1912	6.5	4.2	95	39	134	35.9	46.9	5.0	24.3	8.8	36.5	5,380	1,313	8.0
1913	5.7	3.6	......	......	......	37.1	......	2.0	......	......	......	......	......	......
1914	8.2	4.6	77	29	106	44.4	51.2	4.5	......	11.2	......	4,400	......	10.4
1915	10.2	4.9	84	47	131	52.4	90.2	5.5	42.1	30.7	73.0	10,920	4,600	56.0
1916	9.1	4.4	107	21	128	51.8	65.6	5.0	......	......	......	9,000	......	9.3
Average	9.2	5.2	88	36	125	41.6	......	4.8	......	......	......	......	......	15.4

The average stalk space varied within much closer limits than did the plant space. The closest spacing was 3 inches, the widest was 10.6 inches, and the 8-year average was 5.2 inches. This is a very uniform spacing over a period of eight years and also a very close average spacing for a kafir variety having an average height of about 4.8 feet. In general, the tillering was proportional to the stand. The proportion of suckers varies from 13.8 to 61.4 per cent, the average being 41.6 per cent, or about one sucker to each 1.5 main stalks.

The average acre yield is 15.4 bushels in the 8-year period, as seen in Tables XX and XXI. During the same eight years the average acre yield of five selections of Blackhull kafir was 12.7 bushels, and that of the best one was 14.3 bushels. In 1913 none of the varieties produced any yields whatever, and in 1916 the standard Blackhull selections produced no grain, though Sunrise yielded at the rate of 9.3 bushels per acre. In 1909, Sunrise tied in yield with the best Blackhull kafir, and in 1910 it outyielded all Blackhull selections. In the other four years Sunrise was exceeded in yield by one or more of the standard selections, but never by the same one in all years. These comparisons can be seen to better advantage in Tables XX and XXX.

DAWN (DWARF) KAFIR.

The origin of this dwarf race (C. I. No. 340) has already been stated under Sunrise kafir, the two having developed in 1908 from selection No. 30, grown in the previous year. The chief difference between the two is in height. The original head row of No. 30 in 1907 was heterozygous for stature, but of six head rows grown from it in 1908, two were uniformly dwarf and probably inherently so.

In 1909, 10 head rows were grown from seed of row No. 340–1 of 1908. All the rows were uniformly dwarf and early. To test the purity of this progeny in regard to dwarf stature, 10 heads were selected from the tallest of the dwarf plants and 10 from the lowest. The average difference in the height of the two sets of parents was about 6 or 8 inches. In 1910 the seed from each lot of heads was used to sow 10 head rows. There was absolutely no difference in the progeny of the two lots called, respectively, Nos. 340–1–Ad and 340–1–At.

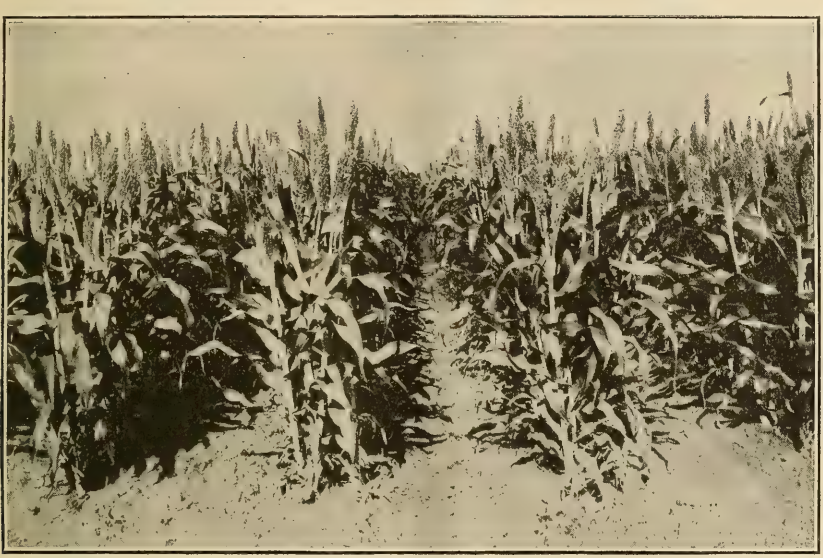

FIG. 10.—A plat of Dawn (Dwarf) kafir, C. I. No. 340, at the Amarillo Cereal Field Station, August 17, 1915; yield, 68.3 bushels per acre.

For six generations since, or nine in all, this race has bred true for dwarf stature and earliness. A plat of Dawn kafir grown at Amarillo, Tex., in 1915, is shown in figure 10.

The number of plats grown in each year in the 9-year period has varied from 1 to 3, the total number being 17. Selection has been practiced within this race in the hope of obtaining still lower stature or earlier maturity, but without special success. The results of the experiments conducted are shown in Tables XX and XXII, and the annual and average yields of this selection are compared with those of other kafirs in Table XXX.

Besides being more dwarf than the ordinary Blackhull kafir, the Dawn kafir is also a little earlier, as will be seen in Table XXII. In 1908, when all varieties developed normally, the difference was about eight days in favor of the Dawn, which gives it about the same earliness as Sunrise kafir. In some seasons this difference was reduced to 1 or 2 days. In 1914, a dry year, and in 1915, a wet year, the difference was increased to 13 or 14 days. In 1916, a very dry year, the Dawn headed about 10 days ahead of the standard kafir and produced some grain, but the standard produced no grain whatever.

TABLE XXII.—*Agronomic data for Dawn (dwarf) kafir grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 60 pounds.]

Year and C. I. No.	Row space.		Length of period.			Suckers.	Headed.	Height of plants.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
1908:	*Ins.*	*Ins.*	*Days.*	*Days.*	*Days.*	*P. ct.*	*P. ct.*	*Feet.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Bus.*
340	14.1	6.8	82	25	107	51.0	......	4.5	......	......	......	......	......	29.0
1909:														
340	12.4	10.5	79	......	......	15.3	78.3	......	......	......	64.9	......	......	14.4
1910:														
340	21.2	8.4	91	35	126	60.4	73.8	4.0	39.0	17.3	44.5	3,363	1,310	9.7
340	23.9	8.6	91	38	129	64.2	63.2	4.0	31.1	14.3	45.9	3,884	1,209	9.3
340	23.7	8.5	90	38	128	64.4	61.3	4.0	30.6	14.6	47.7	3,644	1,117	8.9
Average	22.9	8.5	90.6	37	127.6	63.0	66.1	4.0	33.6	15.4	46.0	3,630	1,212	9.3
1911:														
340	3.4	2.6	79	46	125	24.4	......	5.0	36.3	16.7	45.8	9,320	3,390	35.9
340	9.2	4.9	77	46	123	46.8	......	4.3	48.0	28.3	59.0	7,491	3,600	35.4
340	9.1	5.3	77	46	123	42.3	......	4.3	43.3	20.7	62.3	7,423	3,214	33.4
Average	7.2	4.3	77.7	46	123.7	37.8	......	4.5	42.5	21.9	55.7	8,078	3,401	34.9
1912:														
340	7.7	5.2	95	39	134	32.4	61.5	3.5	46.7	17.6	37.7	3,110	1,453	9.1
340	8.5	4.9	95	39	134	42.2	65.9	3.5	34.3	14.2	41.3	4,990	1,713	11.8
340	7.7	4.6	95	42	137	39.8	52.8	3.5	26.4	8.3	31.6	5,900	1,558	8.0
Average	7.9	4.9	95	40	135	38.1	60.0	3.5	35.8	13.3	36.9	4,666	1,574	9.6
1913:														
340	7.4	4.8	80	......	......	34.7	......	1.5	......	......	......	......	......	......
340	8.1	5.1	80	......	......	36.7	......	1.5	......	......	......	......	......	......
340	7.4	4.5	80	......	......	40.5	......	1.5	......	......	......	......	......	......
Average	7.6	4.8	80	......	......	37.3	......	1.5	......	......	......	......	......	......
1914:														
340	5.7	4.8	73	29	102	15.7	61.8	3.0	......	16.1	......	5,440	......	14.7
1915:														
340	10.2	5.6	81	50	131	45.3	94.8	4.3	49.2	36.1	73.4	8,860	4,360	53.3
1916:														
340	9.1	4.4	118	26	144	50.9	45.2	3.3	......	......	......	5,200	......	3.7

In the matter of germination and stand, the Dawn kafir has been comparable to the ordinary Blackhull kafir and to the Sunrise kafir. In 1908, the plant space was 14.1 inches and in 1910, a dry spring, it was 22.9 inches. The average spacing in the entire period of nine years was 11.4 inches, which is about 1 inch closer than that of Blackhull kafir, but is about 2 inches wider than that of Sunrise kafir. The final stand, or original stalks plus suckers, has been good. The average stalk space is 6.1 inches, compared with 7.6

inches in Blackhull kafir and 5.2 inches in Sunrise kafir. The proportion of suckers to main stalks has exceeded 1 to 1 appreciably only once, in 1910, when the suckers formed 63 per cent of the total stalks. In general, it may be said that the Dawn kafir shows about the same reactions to environment as does the Blackhull kafir except in the matter of earliness and consequent yield, especially in unfavorable seasons.

The average acre yield of Dawn kafir, as shown in Tables XX and XXII, has been 18.8 bushels in the 9-year period, while that of all lots of the ordinary Blackhull kafir has been only 12.3 bushels. During this period the best lot of Blackhull has averaged 17.3 bushels and the average yield of five lots has been 15.3 bushels. During the eight years in which the Sunrise kafir also has been grown and comparison can be made, the average yield of the best selection of Blackhull kafir (C. I. No. 71) was 14.2 bushels, that of the Sunrise kafir was 15.4 bushels, and that of the Dawn kafir was 17.5 bushels per acre. It is in the dry seasons that the Dawn shows its significant advantage over Blackhull kafir. In 1908, a normal season, the Dawn was outyielded by ten selections of Blackhull kafir and by the average of all. In 1915, an abnormally favorable season, its yield was exceeded by those of three out of the six Blackhull selections grown, though not by the average of all. In every other year except 1913, when no yields were obtained from any varieties, it markedly outyielded Blackhull kafir. Not only did it exceed that variety in average yield, but also in the comparative yield of the best plat each year. In fact, the poorest plat of Dawn outyielded the best plat of standard Blackhull in every one of the dry seasons.

WHITE KAFIR.

White kafir has been grown in the United States since the beginning of the experiments with the kafirs. In recent years, however, it has been displaced by the Blackhull kafir, and now it is rarely found in field culture. It differs from the Blackhull kafir in three characters, namely, in white glumes instead of black, in smaller and shorter plants, and in the inability to push the heads completely out of the boot or upper leaf sheath. This last defect probably is only a corollary or expression of the lower vegetative vigor of the variety.

Selection to improve its habits in the matter of the exsertion of the head was begun as early as 1907. The White kafir was normally earlier than the Blackhull kafir. If a race with good heading habits could be produced, it might be a valuable crop in unfavorable seasons and at higher altitudes where the seasons are short. While some progress has been made in producing a race with a more completely exserted head, it has not proved a very high yielder. The results obtained since 1909 are shown in Tables XX and XXIII.

TABLE XXIII.—*Agronomic data for White kafir grown at the Amarillo Cereal Field Station during the 8-year period from 1909 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 60 pounds.]

Year and C. I. No.	Row space.		Length of period.			Suckers.	Headed.	Height of plants.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
	Ins.	*Ins.*	*Days.*	*Days.*	*Days.*	*Per cent.*	*Per cent.*	*Feet.*	*Per cent.*	*Per cent.*	*Per cent.*	*Lbs.*	*Lbs.*	*Bus.*
1909:														
342	13.3	9.9	80	......	......	25.5	48.5	......	......	......	......	......	......	8.7
1910:														
342	17.1	9.0	80	45	125	47.3	82.9	3.6	42.1	18.9	45.0	3,089	1,301	10.1
370	17.3	9.0	80	45	125	47.9	76.8	3.6	37.9	16.6	43.8	3,109	1,178	8.8
Average	17.2	9.0	80	45	125	47.6	79.4	3.6	40.0	17.7	44.4	3,099	1,239	9.9
1911:														
342	8.2	5.8	77	47	124	29.1	......	5.3	42.2	24.3	57.3	6,474	2,754	26.3
370	8.8	5.5	77	47	124	37.6	......	5.3	44.5	25.7	57.9	5,519	2,459	23.7
Average	8.5	5.6	77	47	124	33.3	......	5.3	43.3	25.0	57.6	5,996	2,606	25.0
1912:														
342	9.7	6.4	74	42	116	33.6	86.0	3.3	51.0	35.2	69.0	2,800	1,430	16.5
370	9.1	6.7	74	42	116	26.7	90.2	3.3	62.1	32.3	52.0	2,500	1,553	13.5
Average	9.4	6.5	74	42	116	30.1	88.1	3.3	56.5	33.7	60.5	2,650	1,492	15.0
1913:														
342	11.8	7.8	65	31	96	34.3	......	2.5	......	......	......	......	......	......
70	10.5	7.2	65	31	96	30.7	......	2.5	......	......	......	......	......	......
Average	11.1	7.5	65	31	96	32.5	......	2.5	......	......	......	......	......	......
1914:														
342	8.1	7.2	68	23	91	12.0	74.4	3.8	......	24.7	......	3,560	......	14.7
370	8.0	7.2	68	23	91	10.0	74.4	3.8	......	24.1	......	3,560	......	14.3
Average	8.0	7.2	68	23	91	11.0	74.4	3.8	......	24.4	......	3,560	......	14.5
1915:														
370	10.2	6.9	77	49	126	31.7	97.8	4.8	42.5	35.0	82.4	6,400	2,720	37.3
1916:														
370	14.3	9.2	118	37	155	35.8	48.8	3.0	......	......	......	3,360	......	4.0

The White kafir has much inherent earliness, as is shown by its record in 1913 and 1914, dry years, when the duration of the total growing period was 96 and 91 days, respectively. The much longer duration in all the other years, except 1916, was caused either by slow ripening or the delayed maturing of heads which did not completely emerge from the boot. In general, it is about 10 days earlier than Sunrise kafir and 13 to 15 days earlier than Dawn kafir.

The stands obtained have corresponded rather closely to those of the Dawn kafir. They are better, therefore, than those of the Blackhull kafir, but not as good as those of the Sunrise kafir. The final stand, or stalk space, has been very uniform, but never exceedingly close. It has varied between 5.6 and 9.9 inches per stalk. The proportion of suckers has varied from 11 per cent in 1914 to 47.6 per cent in 1910. Only in that year, however, has the proportion appreciably exceeded one sucker to every two main stalks. The height has varied from about 3 feet to more than 5 feet, the average being about 4 feet.

The average acre yield of White kafir in all eight years is about 15 bushels. This is but little better than that of the average of all selections of Blackhull kafir and much less than that of the Dawn kafir. The comparative yields of all leading kafir varieties will be found in Table XXX. White kafir has exceeded Dawn kafir only once, in 1912, while it fell far below that variety in 1915, the year of bumper crops, when its yield was only 37.3 bushels per acre. Although early in maturing and of dwarf stature and, therefore, presumably at an advantage in the many dry seasons in the past eight years, its performance has been disappointing.

RED KAFIR.

Red kafir differs from the Blackhull subgroup, including the Blackhull, Sunrise, and Dawn varieties, by its much longer and more slender spike and its red-brown seeds. It is one of the two original varieties exhibited by the Orange Free State at Philadelphia in 1876; it was bred in Georgia for many years and finally distributed in the dry-land sections of the southern Great Plains States. In the higher parts of the Panhandle of Texas it has not been as popular as the Blackhull variety, nor has it proved any better as a producer. Careful and long-continued selection so far has failed to improve it sufficiently in this respect.

The number of different selections and races in the plats has varied from seven or eight in the first six years to only two in each of the last three years of the 9-year period from 1908 to 1916, inclusive. The total has been 51 plats in the nine years. The results obtained are presented in Tables XXIV and XXV. The annual and average yields of the best races are compared with those of the other kafirs in Table XXX.

Red kafir is about six or seven days later at Amarillo, on the average, than Blackhull kafir, though in 1915, the very wet year, the Red kafir ripened a week earlier than the Blackhull. Usually the difference in time is distributed proportionately in both the vegetative and fruiting periods. In 1911, however, the vegetative period of Red kafir was three days shorter than that of Blackhull kafir, though the ripening period was eight days longer. In 1910, 1912, and 1914, on the other hand, the ripening period was two to three days shorter, while the vegetative period was two to eight days longer. In 1915 the vegetative periods of the two were of almost identical duration, but the Red kafir ripened in 47 days after heading, while the Blackhull required 54.8 days, or eight days more. The Blackhull had a little wider spacing of plants than the Red kafir, but this was equalized by the production of more suckers, so that the stalk space was the same. The difference in these factors does not seem sufficient to explain the difference in ripening. It is said that under humid conditions the Red kafir is naturally earlier than the Blackhull. The season of 1915 approximated a humid condition in the Texas Panhandle and the early ripening in that year may have been the natural response of this variety to those conditions.

TABLE XXIV.—*Agronomic data for Red kafir grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 60 pounds.]

Year and C. I. No.	Row space.		Length of period.			Suckers.	Headed.	Height of plants.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
1908:	*Ins.*	*Ins.*	*Days.*	*Days.*	*Days.*	*Per ct.*	*Per ct.*	*Feet.*	*Per ct.*	*Per ct.*	*Per ct.*	*Lbs.*	*Lbs.*	*Bush.*
34	8.0	6.5	83	31	114	18.7	......	5.5	......	......	......	......	......	42.7
34-1	12.0	7.0	91	30	121	41.7	......	5.5	......	......	......	......	......	30.1
34-2	......	......	91	32	123	......	......	5.5	......	......	......	......	......	......
68	12.4	7.1	90	28	118	42.7	......	5.5	......	......	......	......	......	37.0
69	12.1	7.1	91	34	125	41.3	......	5.5	......	......	......	......	......	27.7
212	12.2	7.0	91	33	124	42.6	......	5.5	......	......	......	......	......	28.7
215	12.1	7.2	91	33	124	40.5	......	5.5	......	......	......	......	......	32.0
Average	11.5	6.9	89.7	31.5	121.3	37.9	......	5.5	......	......	......	......	......	33.0
1909:														
34-3	7.6	5.4	94	......	......	28.9	8.4	......	......	......	......	......	......	2.0
34-4	6.4	4.2	94	......	......	34.3	4.4	......	......	......	......	......	......	2.0
34-5	6.7	4.5	94	......	......	31.3	14.5	......	......	......	......	......	......	2.0
34	14.7	12.0	93	......	......	18.3	52.1	......	......	......	......	......	......	10.0
68	16.1	12.5	91	......	......	22.3	58.0	......	......	......	......	......	......	10.7
69	14.1	10.1	94	......	......	28.3	29.1	......	......	......	......	......	......	3.0
212	13.1	10.2	94	......	......	22.1	29.9	......	......	......	......	......	......	4.6
215	14.0	10.7	93	......	......	23.5	27.9	......	......	......	......	......	......	5.0
Average	11.6	8.7	93.4	......	......	26.1	28.0	......	......	......	......	......	......	4.9
1910:														
34	46.5	17.6	103	40	143	65.7	48.2	4.5	16.8	9.6	58.0	3,216	531	5.2
68	57.0	19.5	103	40	143	65.6	45.7	4.2	12.5	7.6	60.8	3,326	416	4.2
69	40.5	16.8	[a] 90	38	128	58.5	25.8	4.2	7.5	4.1	53.8	3,526	266	2.4
212	45.7	16.3	103	40	143	64.3	43.6	4.2	12.4	7.3	58.7	3,653	454	4.4
215	53.0	16.5	[a] 90	33	123	68.8	30.0	4.2	8.7	5.0	57.7	3,438	300	2.9
356	27.3	9.1	106	37	143	65.5	42.5	4.2	......	......	......	......	......	7.5
366	24.4	13.0	[a] 90	28	118	46.8	38.5	4.5	......	......	......	......	......	10.7
Average	42.1	15.5	97.8	36.6	134.4	62.2	39.2	4.2	8.2	6.7	57.8	3,432	393	5.3
1911:														
34	16.7	10.9	86	46	132	34.8	......	4.5	39.1	25.7	65.7	4,340	1,700	18.7
68	15.4	10.0	86	46	132	35.1	......	4.5	35.5	23.4	65.5	4,062	1,442	15.8
69	12.5	8.0	88	44	132	36.2	......	4.5	33.9	21.2	62.7	4,935	1,675	17.5
212	11.9	7.6	88	44	132	36.1	......	4.5	36.8	23.6	64.2	4,811	1,771	19.0
215	9.7	6.8	88	44	132	30.5	......	4.5	35.3	21.0	59.0	4,456	1,576	15.6
356	11.3	7.8	86	46	132	31.5	......	4.7	42.3	27.3	64.5	5,340	2,260	24.3
366	16.3	10.4	86	46	132	36.5	......	4.7	[b] 60.3	32.5	64.6	3,078	1,859	20.0
Average	13.4	8.8	86.8	45	132	34.4	......	4.5	40.5	24.9	63.7	4,431	1,754	18.7
1912:														
34	16.8	7.4	[a] 88	51	139	56.2	19.8	4.2	6.2	3.6	57.2	4,973	313	3.0
68	16.8	6.7	[a] 88	51	139	60.1	24.7	4.5	6.8	4.0	58.3	5,735	395	3.8
69	20.0	8.2	[a] 90	49	139	58.8	30.4	4.5	7.0	4.3	61.4	5,355	375	3.8
212	15.9	6.7	[a] 92	47	139	57.9	15.0	4.5	4.4	2.4	55.5	5,235	235	2.2
215	17.1	7.1	[a] 92	47	139	58.5	20.8	4.2	5.3	3.4	64.5	5,513	293	3.1
356	16.2	7.1	99	35	134	56.4	50.8	4.5	33.8	14.7	44.8	4,540	1,495	11.2
366	16.8	7.4	104	34	138	56.0	49.1	4.5	10.9	6.0	55.2	5,775	635	5.8
445	48.0	12.6	95	44	139	73.6	28.8	4.2	5.5	1.6	30.2	4,025	225	1.1
Average	21.2	7.9	93.5	44.5	138	59.7	29.9	4.3	9.9	5.0	53.4	5,143	496	4.3

[a] First and only heads.

[b] Machine headed.

TABLE XXIV.—*Agronomic data for Red kafir grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive*—Continued.

Year and C. I. No.	Row space.		Length of period.			Suckers.	Headed.	Height of plants.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
1913:	*Ins.*	*Ins.*	*Days.*	*Days.*	*Days.*	*Perct.*	*Perct.*	*Feet.*	*Perct.*	*Perct.*	*Perct.*	*Lbs.*	*Lbs.*	*Bus.*
34	10.3	6.4	......	......	......	37.5	......	2.0	......	......	......	......	......	......
68	12.3	7.2	......	......	......	41.3	......	2.0	......	......	......	......	......	......
69	10.2	6.3	......	......	......	38.2	......	2.0	......	......	......	......	......	......
212	10.9	6.5	......	......	......	40.5	......	2.0	......	......	......	......	......	......
215	9.2	5.8	......	......	......	37.0	......	2.0	......	......	......	......	......	......
356	8.8	5.8	......	......	......	31.0	......	2.0	......	......	......	......	......	......
366	8.7	5.9	......	......	......	32.3	......	2.0	......	......	......	......	......	......
445	15.5	5.9	......	......	......	61.7	......	2.0	......	......	......	......	......	......
Average	10.7	6.2	......	......	......	39.9	......	2.0	......	......	......	......	......	......
1914:														
34	9.1	6.9	87	31	118	24.0	65.2	4.0	28.1	18.3	......	4,350	......	13.3
356	5.7	4.9	87	31	118	13.1	56.2	4.0	24.8	16.8	......	4,500	......	15.8
Average	7.4	4.9	87	31	118	18.5	60.7	4.0	26.4	17.5	......	4,425	......	14.6
1915:														
34	10.7	7.9	91	48	139	26.3	96.9	5.5	46.1	35.6	77.3	7,660	3,440	44.3
356	11.5	7.3	89	46	135	36.7	95.2	5.8	......	......	......	......	......	57.0
Average	11.1	7.6	90	47	137	31.5	96.1	5.6	......	......	......	......	......	50.6
1916:														
34	12.5	7.9	127	......	......	36.4	43.2	3.8	......	......	......	4,200	......	......
356	15.4	10.0	127	......	......	35.0	54.0	3.8	......	......	......	3,720	......	......
Average	13.9	9.0	127	......	......	35.7	48.6	3.8	......	......	......	3,960	......	......

The stand obtained from Red kafir has been uniformly poorer than that obtained from Blackhull kafir. On the average, it has been about 35 per cent poorer. The best stand obtained was in 1914, when each plant had only 7.4 inches of space. The poorest was in the very dry spring of 1910, when each plant had 42.1 inches of space. The average has been about 16.5 inches, or about 4 inches more than the average for Blackhull kafir. The difference in stalk space has not been very great, however, owing to the abundant tillering in Red kafir. In 1911 Red kafir was outtillered by the Blackhull kafir, although the Blackhull already had the much thicker stand. In 1914 Blackhull again tillered more than the Red kafir, but in this year it had a thinner stand than the Red. In 1915, when the stand of Blackhull was about 9 per cent thinner than that of Red, its tillering was 6 per cent more. In 1910 and again in 1912, 60 per cent or more of the Red kafir stalks produced were suckers.

The average height of the Red kafir has been about 4.5 feet, which is about the same as that of Blackhull kafir.

The yields obtained in the experiments with Red kafir are shown in Tables XXIV and XXV, and those of the leading selections are compared with the yields of other kafir varieties in Table XXX. A study of the data shows that the best Red kafir has made a 9-year average acre yield of 13.9 bushels, while the best selection of the Blackhull varieties has made an average acre yield of 17.3 bushels in the same period. In two years, 1910 and 1914, the average acre yields of all Red kafir selections have exceeded those of all Blackhull selections. In two other years they have equaled those of the Blackhull selections, in three years they have been lower, and in two years both varieties have failed completely. When only the yield of the best plat in each year is considered, the Red kafir has outranked the Blackhull four times, has been outranked by Blackhull three times, and twice both have failed to produce any grain. The same selection has not been the high-yielding plat in either variety more than two or three times. The annual and average acre yields from each selection, during such part of the 9-year period as they were under experiment, are shown in Table XXV, while the same data from all the Blackhull varieties are shown in Table XX. The highest yield produced by the two varieties was in 1915, when Blackhull yielded 64 bushels and Red kafir 57 bushels per acre. The yields of the leading races of all kafir varieties are compared in Table XXX.

TABLE XXV.—*Annual and average yields of Red kafir grown at the Amarillo Cereal Field Station in periods of varying length during the nine years from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 60 pounds.]

C. I. No.	Annual yields (bushels).									Average yields.				
	1908	1909	1910	1911	1912	1913	1914	1915	1916	4 years, 1910 to 1913.	6 years, 1908 to 1913.	7 years, 1910 to 1916.	9 years, 1908 to 1916.	
										Bus.	*Bus.*	*Bus.*	*Bus.*	*Cwt.*
34	[a]36.4	[b] 4.0	5.2	18.7	3.0	0	13.3	44.3	0	6.7	11.2	12.1	13.9	8.3
68	37.0	10.7	4.2	15.8	3.8	0	......	......	......	6.0	11.9	......	......	......
69	27.7	3.0	2.4	17.5	3.8	0	......	......	......	5.9	9.1	......	......	......
212	28.7	4.6	4.4	19.0	2.2	0	......	......	......	6.4	9.8	......	......	......
215	32.0	5.0	2.9	15.6	3.1	0	......	......	......	5.4	9.8	......	......	......
356	......	......	7.5	24.3	11.2	0	15.8	57.0	0	10.8	......	9.2	......	......
366	......	......	10.7	20.0	5.8	0	......	......	......	9.1	......	......	......	......
445	......	......	......	......	1.1	0	......	......	......	......	......	......	......	......

[a] Average yield from 2 plats. [b] Average yield from 4 plats.

NEW KAFIRS.

Of the varieties and selections grouped under this title, all except one are introductions from South Africa. A list of them will be found in Table XXVI, showing the accession number of the Office of Foreign Seed and Plant Introduction, the date of introduction, the source, and native name, if any. All of them belong to the kafir group, though none of them would be considered identical with varieties now grown in this country. The results obtained in the experiments are shown in Table XXVII. The plat experiments were begun in 1908 with 9 varieties. The number was increased to 12 in 1910 and 1911 and to 14 during each of the next two years. In each of the last three years only 7 varieties have been grown.

TABLE XXVI.—*Data relating to the introduction of 13 new kafirs grown at the Amarillo Cereal Field Station in part or all of the nine years from 1908 to 1916, inclusive.*

Native or other name.	C. I. No.	S. P. I. No.	Date of introduction.	Source.
Blackhull	280	21834	1908	Maiduguri, Bornu, Sudan, Africa.
Unnamed	291	21940	1908	Pretoria, Transvaal, South Africa.
Do.	303	22653	1908	Grahamstown, Cape Colony, South Africa.
Boer kafir	312	19695	1907	Orange River Colony, South Africa.
Unomputshana	314	19739	1907	Cedra, Natal, South Africa.
Bhampi	316	19744	1907	Do.
Umchloenkuku	319	19762	1907	Do.
Bhampi	322	19745	1907	Do.
Jara	323	19749	1907	Do.
Phikhulo	251	19924	1907	Pretoria, Transvaal, South Africa.
Mothlokathlong	252	19925	1907	Do.
Mogathla	253	19926	1907	Do.
Unnamed	321	19737	1907	Cedra, Natal, South Africa.
Hybrid (White kafir)	432	....	1911	Hays Branch Experiment Station, Hays, Kans.

Numerous selections have been made to improve these varieties in height and earliness and in the character of the head, and some progress has been made. Some of the best ones may stand comparison with the selections of standard Blackhull kafir, but none is yet fitted to replace any of the commercial varieties of the United States. Complete data on these varieties are given in Table XXVII, a study of which shows these kafirs to be very diverse in height and earliness. It is impossible, therefore, to consider them together, as for these and other reasons they do not comprise one variety but many. It is desirable, however, to pick out some of the best of them and to compare them as individual varieties. The annual and average yields are given in Table XXVIII.

No. 314, from Natal, is one of the best. It is fairly early, the average duration of the vegetative, fruiting, and entire growing periods being 94, 37, and 131 days, respectively. The shortest growing period was 118 days, in 1914, and the longest was 138 days. In general, the stands have been fair to good, not as good as those of Blackhull kafir, but rather similar to those of Red kafir. Following the very thin stand in 1910, the tillering was enormous, the final result being two suckers to each main stalk. In no other year, however, has the proportion been larger than about one sucker to two main stalks.

The average acre yield of No. 314 is 13.1 bushels in the 8-year period. Two complete failures are recorded, in 1913 and 1916. The yield in 1915 was 46.7 bushels per acre. Had this variety been grown in plats in 1908, the most nearly normal in the whole nine years, its average yield probably would have been about 15 bushels per acre in the nine years.

No. 316, from Natal, is also worthy of consideration. Its growing period is about the same as that of No. 314, the duration of the three periods being 89, 43, and 132 days, respectively. The shortest was 118 days and the longest was 147 days. The stands have been slightly poorer than those of No. 314 on the average. The tillering has been more abundant, however, since in three years the proportion of suckers has exceeded one sucker to each main stalk. The average acre yield in the 8-year period has been 16 bushels, or about 3 bushels better than that of No. 314. Its yield in 1915 was 66 bushels, one of the best made by any kafir variety.

TABLE XXVII.—*Agronomic data for new kafirs grown at the Amarillo Cereal Field Station during the 8-year period from 1909 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 60 pounds.]

Year and C. I. No	Row space.		Length of period.			Suckers.	Headed.	Height of plants.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
	Ins.	*Ins.*	*Days.*	*Days.*	*Days.*	*Per cent.*	*Per cent.*	*Feet.*	*Per cent.*	*Per cent.*	*Per cent.*	*Lbs.*	*Lbs.*	*Bus.*
1909:														
280	......	......	......	......	......	......	......	......	......	......	......	......	......	4.3
291	......	......	82	......	......	......	......	......	......	......	......	......	......	......
303	......	......	81	......	......	......	......	......	......	......	......	......	......	......
312	......	......	88	......	......	......	......	......	......	......	......	......	......	3.3
314	......	......	88	......	......	......	......	......	......	......	......	......	......	9.6
316	......	......	83	......	......	......	......	......	......	......	......	......	......	4.3
319	......	......	87	......	......	......	......	......	......	......	......	......	......	5.3
322	......	......	81	......	......	......	......	......	......	......	......	......	......	......
323	......	......	88	......	......	......	......	......	......	......	......	......	......	......
Average	......	......	84.7	......	......	......	......	......	......	......	......	......	......	5.4
1910:														
291	29.6	9.0	[a] 90	33	123	69.5	18.2	5.5	......	......	......	......	......	2.2
303	35.7	12.8	[a] 90	39	129	64.1	24.3	4.0	......	......	......	......	......	......
323	32.7	10.7	103	35	138	67.3	......	4.0	......	......	......	......	......	......
251	72.0	18.4	97	36	133	74.4	70.9	5.7	......	......	......	......	......	......
316	34.9	10.4	[a] 90	41	131	70.3	24.0	4.2	......	......	......	......	......	......
322	29.6	10.4	[a] 90	38	128	64.8	......	4.0	......	......	......	......	......	4.1
319	46.6	15.7	103	35	138	66.4	60.3	6.2	......	......	......	......	......	7.4
252	39.6	12.0	[a] 90	38	128	69.7	......	7.0	......	......	......	......	......	......
253	33.3	9.8	[a] 100	38	138	70.5	......	7.5	......	......	......	......	......	......
312	37.2	13.1	[a] 90	28	118	64.8	......	5.5	......	......	......	......	......	1.8
314	42.7	14.5	106	32	138	66.0	62.0	5.5	......	......	......	......	......	5.7
321	16.0	6.7	[a] 88	37	125	57.7	......	5.2	......	......	......	......	......	5.3
Average	37.6	11.9	94.7	35.8	130.5	67.1	43.2	5.3	......	......	......	......	......	4.4
1911:														
251	19.1	7.1	74	58	132	63.0	......	6.5	30.4	14.9	49.3	5,397	1,631	13.4
291	10.8	5.8	95	38	133	46.1	......	5.5	47.2	25.1	53.7	5,159	2,419	21.7
323	19.0	9.5	95	38	133	49.6	......	4.3	39.8	22.5	56.5	5,624	2,098	18.1
303	13.3	7.1	88	44	132	41.9	......	4.3	46.2	30.0	64.9	5,754	2,754	29.8
316	16.0	6.7	88	45	133	58.1	......	4.3	48.6	31.6	65.0	5,925	2,885	40.0
319	13.5	7.3	85	47	132	46.0	......	6.5	41.3	27.6	67.0	5,045	2,085	23.3
322	13.9	6.8	88	45	133	51.2	......	4.5	44.5	27.8	62.6	5,626	2,506	26.1
252	12.0	6.5	88	45	133	46.0	......	7.0	37.1	20.7	55.7	7,771	2,887	28.6
253	13.4	6.3	91	42	133	52.7	......	6.8	38.9	18.3	53.1	6,771	2,337	20.7
312	16.5	7.9	91	42	133	52.0	......	6.7	38.1	22.0	59.3	6,627	2,527	25.0
314	11.9	7.8	85	47	132	34.4	......	5.8	46.7	27.2	58.2	5,561	2,601	25.2
321	26.2	12.8	88	45	133	51.1	......	4.8	48.9	32.3	66.0	4,272	2,092	23.0
Average	17.1	7.6	88	44.6	132.6	49.3	......	5.5	42.3	25.0	59.2	5,764	2,401	24.6

[a] First and only heads.

TABLE XXVII.—*Agronomic data for new kafirs grown at the Amarillo Cereal Field Station during the 8-year period from 1909 to 1916, inclusive*—Continued.

Year and C. I. No.	Row space.		Length of period.							Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.	Suckers.	Headed.	Height of plants.	Heads in crop.	Crop.	Heads.	Total crop.	Heads.	Seed.
	Ins.	*Ins.*	*Days.*	*Days.*	*Days.*	*Per cent.*	*Per cent.*	*Feet.*	*Per cent.*	*Per cent.*	*Per cent.*	*Lbs.*	*Lbs.*	*Bus.*
1912:														
251	15.2	4.8	99	30	129	68.2	39.1	5.0	23.2	7.7	33.3	4,860	1,130	6.3
291	10.1	5.1	74	39	138	49.9	29.1	4.8	18.9	6.7	35.7	5,440	1,033	6.1
323	11.7	5.1	*a* 85	54	139	56.7	23.1	4.5	10.1	5.7	56.4	5,095	515	4.8
323	12.4	5.1	*a* 85	54	139	59.2	22.4	4.5	7.8	4.5	57.7	5,640	440	4.2
303	8.4	5.1	*a* 88	52	140	39.0	11.7	4.8	6.4	3.8	59.9	5,578	358	3.5
316	11.2	5.5	*a* 92	55	147	51.1	13.4	4.5	7.7	4.7	61.7	5,938	458	4.7
319	8.8	5.0	*a* 88	59	147	42.9	18.9	6.5	8.1	4.8	59.4	5,575	455	4.5
322	11.9	5.7	*a* 88	59	147	52.3	18.8	4.5	9.0	5.4	60.3	6,820	620	6.2
432	6.2	4.2	95	33	128	29.9	54.9	4.5	18.6	11.0	58.8	6,763	1,263	12.4
252	8.7	5.3	*a* 92	55	147	39.6	10.1	6.8	4.5	2.9	64.3	6,915	315	3.3
253	8.9	4.9	*a* 92	55	147	44.3	12.1	7.0	4.3	2.6	59.8	7,695	335	3.3
312	10.5	5.3	*a* 92	56	148	49.1	11.4	6.8	4.3	2.6	61.1	6,653	293	3.0
314	7.6	6.5	105	31	136	14.6	63.5	5.0	32.7	14.6	44.5	4,860	1,593	11.8
321	8.7	4.9	88	48	136	43.5	20.6	4.5	8.7	5.0	56.8	5,373	473	4.5
Average.	10.0	5.2	92	48.5	140.5	45.7	24.9	5.2	11.7	5.8	54.9	5,943	662	5.6
1913:														
251	11.0	4.8	85	......	......	56.3	......	2.0	......	......	......	......	......	......
291	6.8	4.3	......	......	......	39.5	......	2.0	......	......	......	......	......	......
323	7.5	4.8	......	......	......	35.5	......	2.0	......	......	......	......	......	......
323	6.9	4.1	......	......	......	40.9	......	1.5	......	......	......	......	......	......
303	8.5	4.9	......	......	......	42.7	......	2.0	......	......	......	......	......	......
316	8.2	5.0	......	......	......	38.6	......	2.0	......	......	......	......	......	......
319	9.7	5.8	......	......	......	40.5	......	2.0	......	......	......	......	......	......
322	9.5	5.3	......	......	......	44.2	......	2.0	......	......	......	......	......	......
432	8.3	5.4	......	......	......	34.8	......	2.0	......	......	......	......	......	......
252	11.4	6.3	......	......	......	44.5	......	2.0	......	......	......	......	......	......
253	8.4	5.2	......	......	......	38.8	......	2.0	......	......	......	......	......	......
312	10.6	6.0	......	......	......	43.4	......	2.0	......	......	......	......	......	......
314	7.3	4.9	......	......	......	32.3	......	2.0	......	......	......	......	......	......
321	7.5	4.9	......	......	......	35.0	......	2.0	......	......	......	......	......	......
Average.	8.6	5.1	......	......	......	40.5	......	1.9	......	......	......	......	......	......
1914:														
291	4.6	4.0	87	25	112	13.1	29.6	5.0	17.9	10.9	......	4,580	820	8.3
303	6.7	4.6	87	31	118	31.0	31.0	3.5	16.9	10.8	......	4,260	720	7.7
316	9.8	6.1	87	31	118	37.5	41.6	3.5	27.8	18.2	......	4,160	1,160	12.7
432	5.0	4.4	87	25	112	12.0	38.0	4.0	20.6	13.8	......	4,060	840	9.3
252	11.1	6.2	87	31	118	44.7	22.0	5.5	11.3	7.6	......	4,940	560	6.3
314	5.8	5.1	87	31	118	12.6	36.0	4.3	14.7	8.2	......	4,340	640	6.0
321	7.3	5.3	87	31	118	27.3	30.1	3.8	17.5	10.6	......	3,760	660	6.7
Average.	7.2	5.1	87	29.2	116.2	25.5	32.7	4.2	18.1	11.4	......	4,300	771	8.1
1915:														
291	10.1	6.8	91	41	132	32.6	96.6	6.3	......	......	......	......	......	44.7
303	10.2	7.0	89	42	131	31.2	92.5	4.3	......	......	......	......	......	51.0
316	10.2	6.6	91	40	131	35.1	97.0	4.8	......	......	......	......	......	66.0
432	10.2	6.0	84	52	136	40.9	92.5	4.8	......	......	......	......	......	59.7
252	11.6	6.6	94	45	139	44.1	96.5	7.3	......	......	......	......	......	50.7
314	11.3	8.6	87	45	132	23.5	98.2	5.3	......	......	......	......	......	46.7
321	10.2	6.1	89	43	132	40.1	99.8	5.5	......	......	......	......	......	54.7
Average.	10.6	6.8	89	44	133	35.4	96.1	5.5	......	......	......	......	......	53.3
1916:														
291	8.4	5.9	127	......	......	29.5	39.6	4.3	......	......	......	3,625	......	......
303	12.6	10.4	130	......	......	18.1	24.2	3.3	......	......	......	1,800	......	......
316	21.2	14.6	126	......	......	31.2	58.6	3.5	......	......	......	2,400	......	......
432	14.0	8.4	128	17	145	39.6	29.2	3.3	......	......	......	2,160	......	2.0
252	13.4	9.6	125	......	......	27.8	59.5	5.0	......	......	......	1,800	......	......
314	17.7	12.8	127	......	......	27.9	59.9	4.5	......	......	......	2,440	......	......
321	11.2	7.0	130	......	......	38.0	27.4	3.3	......	......	......	3,160	......	......
Average.	14.1	9.8	127	......	......	30.3	42.6	3.9	......	......	......	2,463	......	......

a First and only heads.

Some of the other promising varieties are Nos. 303, grown during eight years, No. 321, grown in seven years, and No. 432, grown during five years. Comparative results will be found in Table XXVIII. The 8-year average acre yield of No. 303 is 11.5 bushels. The 7-year average acre yields of Nos. 303 and 321 are 13.1 and 13.5 bushels, respectively. The 5-year average acre yields of the three numbers are 12.4, 12.8, and 16.7 bushels, respectively.

Table XXVIII.—*Annual and average yields of all lots of new kafirs grown at the Amarillo Cereal Field Station during periods of varying length in the eight years from 1909 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 60 pounds.]

C. I. No.	Annual yields (bushels)								Average yields.				
	1909	1910	1911	1912	1913	1914	1915	1916	4 years, 1910 to 1913.	5 years—		8 years, 1909 to 1916.	
										1909 to 1913.	1912 to 1916.		
									Bus.	*Bus.*	*Bus.*	*Bus.*	*Cwt.*
251			13.4	6.3									
291		2.2	21.7	6.1		8.3	44.7		7.5		11.8		
323			18.1	4.8									
303			29.8	3.5		7.7	51.0				11.2		
316	4.3		40.0	4.7		12.7	66.0		11.2	9.8	16.7	16.0	9.6
319	5.3	7.4	23.3	4.5					8.8	8.1			
322		4.1	26.1	6.2					9.1				
432				12.4		9.3	59.7	2.0			16.7		
252			28.6	3.3		6.3	50.7				12.1		
253			20.7	3.3									
312	3.3	1.8	25.0	3.0					7.5	6.6			
314	9.6	5.7	25.2	11.8		6.0	46.7		10.7	10.4	12.9	13.1	7.9
321		5.3	23.0	4.5		6.7	54.7		8.2		13.2		
280	4.3												

GUINEA KAFIR.

The variety here called Guinea kafir is an old variety in this country which is not now grown commercially, so far as known. It was widely advertised and tested 50 years or so ago under various names. Among them were such as "Rural Branching Sorghum," "White Millo Maize," etc. It was then grown to some extent in the Southern States, being too late to mature anywhere else. Although carefully tested both in the nursery and in field plats at the Amarillo Cereal Field Station, it has shown no adaptation for the dry lands.

It is too tall, too late in maturing, and too poor a yielder of grain to be of commercial value, even under conditions more favorable than those of the Texas Panhandle. Some popular interest still attaches to it, and for this reason it has been carried in the experiments during the entire nine years. The results obtained are shown in Table XXIX and comparatively in Table XXX and prove how poor it is under such conditions. Even in 1915 it was unable to make a better yield than 35 bushels per acre.

TABLE XXIX.—*Agronomic data for Guinea kafir grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 60 pounds.]

Year and C. I. No.	Row space.		Length of period.							Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.	Suckers.	Headed.	Height of plants.	Heads in crop.	Crop.	Heads.	Total crop.	Heads.	Seed.
1908:	*Ins.*	*Ins.*	*Days.*	*Days.*	*Days.*	*P. ct.*	*P. ct.*	*Feet.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Bus.*
73			96	45	141			7.5						
1910:														
73	28.0	8.8	[a] 90	53	143	68.1		6.5						
1911:														
73			[a] 106					6.0						
1912:														
73	16.5	6.1	111	36	147	62.9	32.4	5.5	6.2	3.6	59.1	13,650	850	8.4
484	23.3	9.4	111	32	143	59.5	61.9	4.5	14.8	8.7	59.1	8,338	1,238	12.1
Average	19.9	7.7	111	34	145	61.2	47.1	5.0	10.5	6.2	59.1	10,994	1,044	10.2
1913:														
73	9.5	4.9				48.0		2.0						
484	11.1	6.5				41.2		2.0						
Average	10.3	5.7				44.6		2.0						
1914:														
73	9.8	5.6	87	35	122	44.2	3.9	5.0	3.4	2.4		4,120	175	2.1
1915:														
73	12.0	6.3	107	53	160	47.7	93.5	7.5						35.0
1916:														
73	36.0	16.0	128			54.4		3.5				1,700		

[a] First and only heads.

COMPARATIVE YIELDS OF THE KAFIR GROUP.

The annual and average acre yields of the leading races in each variety of the kafir group are given in Table XXX. The average yields are given for the 7-year, the 8-year, and the full 9-year periods. The table contains yields of 17 lots, of which 5 are Blackhull, 1 Sunrise, 1 Dawn (dwarf), 1 White, 2 Red, and 7 new kafirs. Seven of the lots have been grown throughout the 9-year period.

In the seven years from 1910 to 1916, inclusive, the Dawn, the Sunrise, and C. I. No. 316, one of the new varieties, lead with average acre yields between 17.5 and 17.9 bushels, that of the Dawn variety being highest. A Red kafir (C. I. No. 356) stands next with an average acre yield of 16.5 bushels, and Blackhull (C. I. No. 71) ranks fifth with an average yield of 15.7 bushels per acre. In the 8-year period the same three varieties lead, and Blackhull (C. I. No. 71) again holds fifth place. Fourth place is taken by Blackhull (C. I. No. 335), the Red (C. I. No. 356) having been grown only seven years.

In the 9-year period, Dawn kafir still leads with an average acre yield of 18.8 bushels. Sunrise has been grown only eight years and Blackhull (C. I. No. 71) advances to second place with an average yield of 17.3 bushels. Third and fourth places are occupied by Blackhull selections, with average acre yields of 16.9 and 16.5 bushels, respectively. Blackhull and Red selections tie for fifth place with average yields of 13.9 bushels.

The breeding of the early variety, Sunrise, and the early and dwarf variety, Dawn, is seen to be justified by the outstanding favorable results.

TABLE XXX.—*Annual and average acre yields of the leading varieties and races in each of the subgroups of the kafir group of grain sorghums grown at the Amarillo Cereal Field Station in most or all of the nine years from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 60 pounds.]

Variety and C. I. No.	Annual yields (bushels).									Average yields.			
	1908	1909	1910	1911	1912	1913	1914	1915	1916	7 years, 1910 to 1916.	8 years, 1909 to 1916.	9 years, 1908 to 1916.	
										Bus.	*Bus.*	*Bus.*	*Cwt.*
Blackhull:													
71	42.2	3.5	1.0	26.5	4.7	0	14.0	64.0	0	15.7	14.2	17.3	10.4
204	31.4	10.9	5.5	19.0	9.2	0	10.7	38.3	0	11.8	11.7	13.9	8.3
207	32.6	6.3	4.4	11.4	4.5	0	10.0	35.7	0	9.4	9.4	11.7	7.0
335	37.0	10.7	4.8	20.6	4.6	0	11.3	62.7	0	14.9	14.3	16.9	10.1
337	38.3	7.7	3.5	21.0	4.7	0	9.3	64.0	0	14.6	13.8	16.5	9.9
Sunrise:													
472	......	10.8	7.6	21.4	8.0	0	10.4	56.0	9.3	17.5	15.4	......	......
Dawn (dwarf):													
340	29.0	14.4	9.3	34.9	9.6	0	14.7	53.3	3.7	17.9	17.5	18.8	11.3
White:													
370	......	......	8.8	23.7	13.5	0	14.3	37.3	4.0	14.5	......	......	......
Red:													
34	36.4	4.0	5.2	18.7	3.0	0	13.3	44.3	0	12.1	11.1	13.9	8.3
356	......	......	7.5	24.3	11.2	0	15.8	57.0	0	16.5	......	......	......
New African:													
291	......	0	2.2	21.7	6.1	0	8.3	44.7	0	11.9	10.4	......	......
303	......	0	0	29.8	3.5	0	7.7	51.0	0	13.1	11.4	......	......
316	......	4.3	0	40.0	4.7	0	12.7	66.0	0	17.6	16.0	......	......
432	......	......	......	......	12.4	0	9.3	59.7	2.0	......	......	......	......
252	......	......	0	28.6	3.3	0	6.3	50.7	0	12.7	11.1	......	......
314	......	9.6	5.7	25.2	11.8	0	6.0	46.7	0	13.6	13.1	......	......
321	......	......	5.3	23.0	4.5	0	6.7	54.7	0	13.5	......	......	......

THE KAOLIANG GROUP.

The kaoliangs are grain-producing varieties of sorghum from China and Manchuria. The most important varieties have been separated by a simple key (p. 17). The group has been quite fully described by the senior writer[1] in a previous publication.

The kaoliangs are very diverse in height, earliness, and productiveness. So far, only one variety, the Manchu, has become commercially important in the United States. All have dry pithy stems, and many of them are fairly early, presumably with rather low water requirements. However, those which are early enough to be valuable have never been able to compete in yield with Dwarf milo, milo, Sunrise kafir, etc., except at the extreme northern edge of the sorghum belt, as in South Dakota. The varieties grown are presented in three subgroups, White, Blackhull, and Brown, in Tables XXXI to XXXVI, inclusive.

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[1] Ball, C. R. The kaoliangs: A new group of grain sorghums. U. S. Dept. Agr., Bur. Plant Indus. Bul. 253, 64 p., 15 fig., 1 pl. 1913.

THE WHITE KAOLIANG SUBGROUP.

Only two varieties of white-glumed, white-kerneled kaoliang have been under experiment. Both were grown during the first six years, though the yield made by Mukden (C. I. No. 190) in 1908 is missing. Only the one variety was grown in each of the last three years. The chief disadvantage of the varieties has been their height, which ranged from 6 to 8 feet and made them subject to lodging in wet or windy weather. Nor have they been good yielders. The complete data obtained are presented in Table XXXI. Annual and average yields of the White and Blackhull subgroups are compared in Table XXXIII, while the yields of all three subgroups are compared in Table XXXVI.

TABLE XXXI.—*Agronomic data for White kaoliang grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

Year and C. I. No.	Row space.		Length of period.			Suckers.	Headed.	Height of plants.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
	Ins.	*Ins.*	*Days.*	*Days.*	*Days.*	*P. ct.*	*P. ct.*	*Feet.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Bus.*
1908:														
190	9.7	6.8	69	55	124	29.9	......	6.7	......	......	......	......	......	......
272	7.5	5.7	67	29	96	24.0	......	8.0	......	......	......	......	......	18.1
Average.	8.6	6.3	68	42	110	26.9	......	7.3	......	......	......	......	......	18.1
1909:														
190	11.6	11.1	70	40	110	4 3.	......	......	......	......	......	......	......	12.8
272	10.1	9.8	71	41	112	2.8	......	......	......	......	......	......	......	15.7
Average.	10.8	10.4	70.5	40.5	111	3.5	......	......	......	......	......	......	......	14.2
1910:														
190	19.3	10.3	78	40	118	46.8	90.7	6.5	47.6	27.7	58.4	2,540	1,210	12.2
272	12.8	7.5	90	28	118	41.2	76.7	6.7	......	......	......	......	......	7.2
Average.	16.0	8.9	84	34	118	44.0	83.7	6.6	47.6	27.7	58.4	2,540,	1,210	9.7
1911:														
190	7.7	6.7	74	27	101	12.9	100	8.0	51.0	31.5	60.9	4,614	2,354	25.1
272	6.0	5.3	72	29	101	11.2	100	7.5	49.4	28.3	57.6	4,312	2,132	21.2
Average.	6.8	6.0	73	28	101	12.0	100	7.7	50.2	29.9	59.2	4,463	2,243	23.1
1912:														
190	7.2	6.6	84	37	121	7.6	92.3	6.0	34.0	13.2	37.4	3,680	1,253	8.4
272	7.0	5.7	84	37	121	17.9	87.2	6.5	41.8	22.6	54.1	4,720	1,973	18.4
Average.	7.1	6.1	84	37	121	12.7	89.7	6.2	37.9	17.9	45.7	4,200	1,613	13.4
1913:														
190	7.8	7.2	71	32	103	7.3	......	3.5	......	......	......	......	......	......
272	7.0	6.5	71	32	103	7.5	......	3.5	......	......	......	......	......	......
Average.	7.4	6.8	71	32	103	7.4	......	3.5	......	......	......	......	......	......
1914:														
190	7.2	6.5	64	26	90	9.5	76.9	6.0	32.8	18.5	56.5	4,666	1,533	14.9
1915:														
190	41.9	28.8	68	44	112	31.3	82.2	8.0	30.9	20.9	67.7	3,820	1,180	13.8
1916:														
190	17.2	13.1	77	28	105	24.1	86.2	5.5	......	10.6	......	1,880	......	3.4

Table XXXI shows that the duration of the growing period has varied from 90 days, in 1915, to 121 days, in 1912. Their earliness, therefore, is comparable to that of the milo group and indicates some promise of usefulness in this particular line.

The stand obtained has varied considerably in the different years. In 1910, when the spring was extremely dry, the stand was better than that of any of the kafirs or milos. The poorest stand was obtained in the wet spring of 1915, when each plant had 42 inches of space and the sucker production of 31.3 per cent reduced the stalk space to only 29 inches. Sucker production in 1910 averaged 44 per cent of the total number of stalks, while the percentage in 1915 was the next highest.

The yield of Mukden (C. I. No. 190) is only 11.3 bushels per acre in the eight years for which the record exists, there being no record in 1908. The average acre yields of the two varieties in the five years from 1909 to 1913, inclusive, in which both were grown, were only 11.7 and 12.5 bushels, respectively. These yields are too small to be very encouraging. The yield of No. 190 in 1915, the year of bumper yields, was only 13.8 bushels per acre, due partly to the very thin stand, no doubt, but not indicating high productiveness under favorable conditions. The annual and 9-year average yields of White kaoliang are compared with those of other kaoliangs in Table XXXVI.

THE BLACKHULL KAOLIANG SUBGROUP.

This subgroup of kaoliangs is distinguished by black glumes and white kernels. Three different introductions have been under experiment in varying numbers of years in the 9-year period from 1908 to 1916, inclusive. The results are given in Tables XXXII and XXXIII. Only one of these varieties has proved at all promising. Brill (C. I. No. 120) was too tall to be satisfactory and too late to make good yields and was discarded at the end of six years. Korean (C. I. No. 412) also was tall and late and frequently gave only thin stands. It was placed in the experiment in 1910, continued for five years, and discarded at the end of 1914. Only Barchet (C. I. No. 310) has been carried throughout the 9-year period.

The stands obtained from the Barchet variety have been unusually uniform. The 9-year average plant space has been only 8.4 inches. The closest spacing was 3 inches in 1914, and the widest spacing 14.2 inches in 1916. In the dry spring of 1910 and the wet spring of 1915 the plant spacings were 13.8 and 10.7 inches, respectively, much closer than in most of the milos and kafirs. The average stalk space has been only 5.5 inches. The closest spacing was 2.7 inches, in 1914, when the plant space was only 3 inches. The widest spacing was 8.2 inches, in 1909, when the plant space was 8.9 inches and only 7 per cent of suckers were produced. Tillering has been in direct proportion to stand except in the year 1909. The average production of suckers has been about 28 per cent, or about 1 sucker to every 2.5 main stalks. The lowest production was 4.4 per cent, in 1914, and the highest was 56.4 per cent, in 1910. In no other year did the proportion exceed 1 sucker to each main stalk, though in 1916 this proportion was closely approximated.

TABLE XXXII.—*Agronomic data for Blackhull kaoliang grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

Year and C. I. No.	Row space.		Length of period.							Seed in—		Yield per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.	Suckers.	Headed.	Height of plants.	Heads in crop.	Crop.	Heads.	Total crop.	Heads.	Seed.
1908:	*Ins.*	*Ins.*	*Days.*	*Days.*	*Days.*	*P. ct.*	*P. ct.*	*Feet.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Bus.*
120	14.1	7.2	78	47	124	48.9	......	7.9	......	......	......	......	......	......
310	9.7	6.0	74	26	100	38.2	......	5.0	......	......	......	......	......	43.1
Average	11.9	6.6	76	36.5	112.5	43.5	......	6.4	......	......	......	......	......	43.1
1909:														
120	11.4	9.5	92	......	......	16.6	......	......	......	......	......	......	......	......
310	11.6	10.4	75	......	......	10.3	......	......	......	......	......	......	......	9.4
310	10.9	10.1	72	......	......	7.3	......	......	......	......	......	......	......	9.4
310	6.8	6.4	77	......	......	5.8	......	......	......	......	......	......	......	9.4
310	6.2	5.9	81	......	......	4.8	......	......	......	......	......	......	......	9.6
Average	9.4	8.5	79.4	......	......	8.9	......	......	......	......	......	......	......	9.4
1910:														
120	16.8	7.1	90	30	120	56.6	36.6	7.2	......	......	......	......	......	1.8
310	13.8	6.0	90	21	111	56.4	65.3	4.2	38.1	18.0	47.3	2,766	1,053	8.6
412	23.7	10.1	85	34	110	57.3	80.3	7.0	......	......	......	......	......	10.3
Average	18.1	7.7	88.3	28.3	116.6	56.8	60.7	6.1	38.1	18.0	47.3	2,766	1,053	6.9
1911:														
120	15.1	10.0	73	35	108	33.8	100	7.0	49.5	28.2	58.4	3,965	1,915	19.3
412	11.4	6.4	78	30	108	43.3	100	7.0	38.9	21.3	55.1	4,337	1,687	16.0
310	5.7	4.6	73	35	108	18.5	100	5.3	55.9	34.3	61.3	5,333	2,984	31.6
310	6.6	4.3	73	35	108	34.0	100	5.3	48.2	28.2	58.7	6,310	3,045	30.7
310	6.0	4.3	73	35	108	29.3	100	5.3	61.0	36.6	60.0	4,750	2,900	30.0
Average	8.9	5.9	74	34	108	31.8	100	5.9	50.7	29.7	58.7	4,979	2,506	25.3
1912:														
120	6.4	4.8	87	34	121	25.3	14.7	6.0	43.5	21.1	48.3	4,200	1,830	15.3
412	22.9	6.4	87	34	121	72.5	100.0	6.0	49.0	25.8	52.6	4,060	1,993	18.1
310	5.3	4.0	84	26	110	23.7	87.2	4.0	46.4	26.1	56.2	4,030	1,873	18.2
310	3.6	3.3	87	23	110	8.3	76.3	4.0	37.6	18.2	42.2	3,900	1,470	12.2
310	3.4	3.2	91	19	110	5.8	76.4	4.0	39.9	18.8	47.1	3,980	1,590	12.9
Average	8.3	4.3	87	27	114	27.1	82.9	4.8	43.2	22.0	49.3	4,034	1,751	15.3
1913:														
120	5.9	4.9	71	25	96	16.8	......	2.5	......	......	......	......	......	......
412	9.8	6.1	75	33	108	37.3	......	2.5	......	......	......	......	......	......
310	6.4	5.0	75	27	102	21.7	......	2.5	......	......	......	......	......	......
310	6.2	4.8	75	27	102	22.0	......	2.5	......	......	......	......	......	......
Average	7.1	5.2	74	28	102	24.4	......	2.5	......	......	......	......	......	......
1914:														
310	3.0	2.7	71	25	96	4.4	34.3	4.0	......	11.1	......	3,240	......	6.2
412	4.0	3.8	66	30	96	6.2	50.5	4.5	34.4	13.3	38.7	4,500	1,550	10.4
Average	3.5	3.3	68.5	27.5	96	5.2	42.4	4.3	34.4	12.2	38.7	3,870	1,550	8.3
1915:														
310	10.7	6.3	65	38	103	41.3	94.8	5.3	52.6	39.3	74.7	6,760	3,560	45.8
412	22.6	9.3	68	41	109	58.8	94.1	7.0	......	......	......	5,333	......	32.2
Average	16.7	7.8	67	39	106	50.0	94.5	6.1	52.6	39.3	74.7	6,046	3,560	39.0
1916:														
310	14.2	7.5	77	47	124	47.2	43.2	3.0	......	9.4	......	2,120	......	3.4

Barchet kaoliang is fairly early in maturing. The data cover only eight years, the record of 1909 being incomplete. The average duration of the vegetative period is 76.5 days, of the fruiting period 30.5 days, and of the entire growing period only 107 days. This period is of about the same length as that of milo and Dwarf milo, but is more than two weeks shorter than that of even the earliest kafir. The shortest growing period recorded is 96 days, in 1914, when the duration of the vegetative period was only 71 days and the fruiting period only 25 days. In that year, however, only the earliest heads appeared. The longest growing period recorded is 124 days, in 1916, when the vegetative period occupied only 77 days, but the fruiting period was prolonged by drought to 47 days, the longest yet recorded for this variety. The shortest fruiting period was 21 days, in 1910, correlated, however, with the longest vegetative period, or 90 days. The shortest vegetative period was 65 days, in 1915, a year of abundant moisture, in which this variety ripened in 103 days, while most of the grain sorghums required more than their average time in which to mature.

The average height of the Barchet kaoliang is 4.3 feet under the conditions obtaining at Amarillo in the last nine years. The lowest stature in any year in which grain matured was 3 feet, in 1916. The tallest growth was made in 1911 and 1915, when its height was 5.3 feet.

TABLE XXXIII.—*Annual and average acre yields of all lots of White and Blackhull kaoliang grown at the Amarillo Cereal Field Station during periods of varying length in the nine years from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

Subgroup and varieties.	C. I. No.	Annual yields (bushels).									Average yields.			
		1908	1909	1910	1911	1912	1913	1914	1915	1916	6 years— 1908 to 1913.	6 years— 1910 to 1915.	8 years, 1909 to 1916.	
White:											*Bus.*	*Bus.*	*Bus.*	*Cwt.*
Mukden	190	......	12.8	12.2	25.1	8.4	0	14.9	13.8	3.4	......	12.4	11.3	6.6
Do	272	18.1	15.7	7.2	21.2	18.4	0	......	......	......	13.4	......	......	......
Blackhull:														
Brill	120	......	......	1.8	19.3	15.3	0	......	......	......	......	......	......	......
Barchet	310	43.1	[a]9.4	8.6	[a]30.7	[a]14.4	0	6.2	45.8	3.4	17.7	17.6	14.8	8.7
Korean	412	......	......	10.3	16.0	18.1	0	10.4	32.2	......	......	14.3	......	......

[a] Average of three plats.

The annual and average acre yields of Barchet kaoliang in the 9-year period are shown in Table XXXIII, compared with those of White kaoliang. The 9-year average yield has been 18 bushels, based on the records of 16 plats. This average yield is from 4 to 10 bushels lower than those of the milos and feterita, is a little lower than those of White durra and Dawn kafir, and is better than those of either Blackhull or Red kafir. Barchet kaoliang was able to make a small yield in 1916, when the later kafirs did not produce any grain. The highest yield made was 45.8 bushels, in 1915. Many of the grain sorghums made much better yields in that year. The lowest yield, excepting the failure of 1913, was 3.4 bushels, in 1916. In 1911 this variety made the very good yield of 30.8 bushels as the average of three plats. The annual and average yields of the Barchet are compared with those of leading varieties of the White and Brown subgroups in Table XXXVI.

THE BROWN KAOLIANG SUBGROUP.

The Brown kaoliang subgroup contains a numerous collection of very diverse varieties. Some are early, some midseason, and some late. Some are dwarf, some midsized, and some tall. Some have very compact heads; others have open and spreading panicles. All are introductions from China and Manchuria. Almost all of them were mixed when received, and many of them contained hybrids, probably due to their having been grown in mixtures in their native land.

Those varieties which the preliminary experiments showed to have some promise for American conditions have been carefully selected and better races developed. For the most part, however, they have not been able to compete with the milo and kafir varieties in yield. No less than 33 varieties and selections of these brown-seeded kaoliangs have been grown. There were 19 when the experiment was begun in 1908. The maximum number in any one year was 23, in 1913, and the smallest number grown was 8, in 1915 and 1916. The results obtained are presented in Tables XXXIV and XXXV.

Since the varieties included in this subgroup are so very diverse, it is impossible to interpret their performance and value by a discussion of average results. It is possible, however, to present the average results obtained from two or three of the best varieties. The most promising of all, and the only one that has any commercial importance, is Manchu (C. I. No. 171). It was obtained from Japan, but without any doubt is a native of Manchuria, whence other almost identical forms have been derived. Figure 11 shows a plat of Manchu kaoliang (C. I. No. 171) grown at Amarillo, Tex., in 1908.

The most prominent characteristic of Manchu kaoliang has been its earliness. In 1908, a fairly normal season, it matured in 89 days, of which the vegetative period occupied 62 and the fruiting period 27 days. The only other variety as early was C. I. No. 261, an almost identical form of this variety, but not as good a yielder. The shortest growing period was 80 days, in 1914, and the next was 83 days, in 1909. In these two years the yields were 20 and 18.1 bushels per acre, respectively. The average duration of the growing period has been 93 days, of which an average of 65 days has been occupied by the vegetative period and 28 days by the fruiting period. The shortest vegetative period was 60 days, in 1914, and the shortest fruiting period 19 days, in 1909, a very dry year. The longest vegetative period was 73 days, in 1912, and the longest fruiting period 36 days, in 1910, a very dry year, and again in 1915, a very wet season. It is noteworthy that in 1909 three selections matured in 83 days, while four others required 91 days, the difference being wholly in the fruiting period and caused perhaps more by the thinner stand of the latter than by any other reason. The average stalk space in the three early lots was 3.4 inches, while in the four later lots it was 9.1 inches.

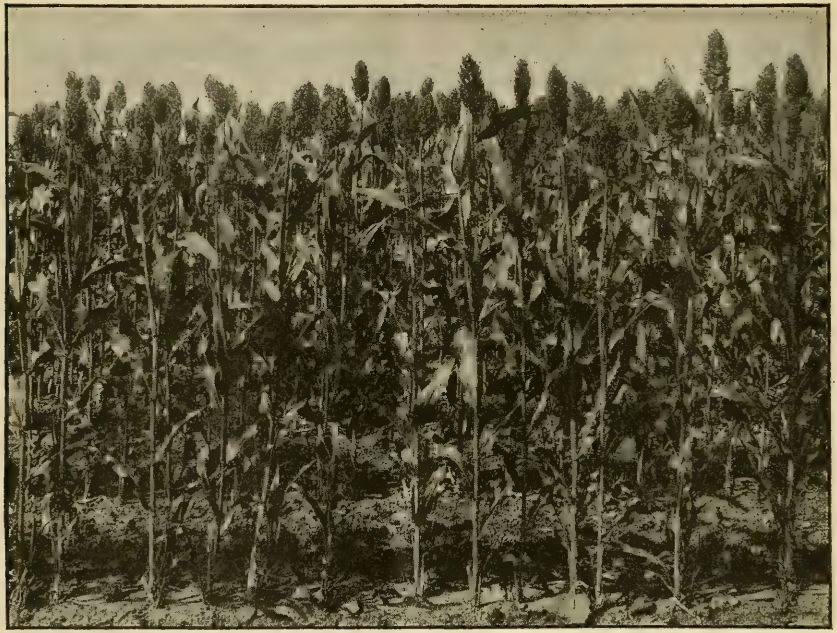

FIG. 11.—A Plat of Manchu kaoliang (C. I. No. 171) at the Amarillo Cereal Field Station, August 20, 1908

The stand obtained from Manchu kaoliang has been remarkably uniform. The closest spacing has been 3.4 inches and the widest 25.5 inches, which occurred in 1916. In 1910 the spacing was one plant to each 14 inches. Only in these two years did the spacing exceed 8 inches. The 9-year average plant space was only 8.7 inches. In the eight years, omitting 1916, the stalk space ranged from 3.4 inches to 7.1 inches. In that year, when the plant space was 25.5 inches, the stalk space was reduced only to 17.7 inches by the 30.8 per cent of suckers produced. The average stalk space in the nine years was 6.5 inches.

TABLE XXXIV.—*Agronomic data for Brown kaoliang grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

Year and C. I. No.	Row space.		Length of period.			Suckers.	Headed.	Height of plants.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
	Ins.	*Ins.*	*Days.*	*Days.*	*Days.*	*P. ct.*	*P. ct.*	*Feet.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Bus.*
1908:														
122–2	8.0	6.7	75	28	103	16.3	......	5.6	......	......	......	......	......	33.9
122–3	......	......	75	28	103	......	......	5.6	......	......	......	......	......	......
123–1	9.0	7.4	75	29	104	17.6	......	6.5	......	......	......	......	......	31.3
123–2	......	......	75	29	104	......	......	6.5	......	......	......	......	......	......
171–A	7.5	6.4	63	27	90	14.6	......	5.0	......	......	......	......	......	37.4
171–B	7.4	6.0	62	27	89	18.9	......	4.5	......	......	......	......	......	28.2
171–C	6.4	5.1	62	27	89	20.3	......	5.0	......	......	......	......	......	34.6
171–10	7.4	6.0	62	27	89	18.9	......	5.0	......	......	......	......	......	......
171–12	......	......	62	27	89	......	......	5.0	......	......	......	......	......	......
191	8.3	7.4	68	27	95	10.8	......	5.5	......	......	......	......	......	......
192	8.8	8.0	68	26	94	9.0	......	6.0	......	......	......	......	......	25.6
193	8.7	8.0	68	27	95	8.0	......	6.0	......	......	......	......	......	26.3
261	8.7	6.7	62	23	85	11.5	......	6.0	......	......	......	......	......	20.9
263	......	......	62	33	95	......	......	6.0	......	......	......	......	......	......
265	......	......	62	28	90	......	......	5.0	......	......	......	......	......	......
152	......	......	73	29	102	......	......	7.0	......	......	......	......	......	......
273	7.9	3.4	67	31	98	56.9	......	7.0	......	......	......	......	......	......
293	......	......	73	40	113	......	......	2.5	......	......	......	......	......	33.6
309	8.0	4.9	73	26	99	38.7	......	6.0	......	......	......	......	......	37.4
Average.	8.0	6.3	67.7	28.3	96.1	20.1	......	5.5	......	......	......	......	......	30.9
1909:														
122–2	12.7	12.5	70	28	98	1.5	......	......	......	......	......	......	......	14.4
122–3	11.1	11.0	70	28	98	.9	......	......	......	......	......	......	......	15.1
123	10.0	9.9	70	28	98	1.0	......	......	......	......	......	......	......	9.9
171–1	9.1	9.0	63	29	92	1.1	......	......	......	......	......	......	......	14.3
171–2	9.4	9.2	64	28	92	2.1	......	......	......	......	......	......	......	11.8
171–9	8.9	8.9	64	26	90	0	......	......	......	......	......	......	......	9.7
171	4.0	3.9	64	19	83	2.5	......	......	......	......	......	......	......	16.2
171	3.3	3.3	64	19	83	0	......	......	......	......	......	......	......	15.3
171	3.0	3.0	64	19	83	0	......	......	......	......	......	......	......	22.8
171–9–10	9.5	9.4	64	26	90	1.0	......	......	......	......	......	......	......	9.1
193	11.5	11.3	66	27	93	1.7	......	......	......	......	......	......	......	12.8
261	8.3	8.2	59	21	80	1.2	......	......	......	......	......	......	......	11.4
293	11.2	11.1	66	33	99	.9	......	......	......	......	......	......	......	3.5
309	9.0	8.5	66	25	91	5.5	......	......	......	......	......	......	......	16.0
323	......	......	87	......	......	......	......	......	......	......	......	......	......	......
324	......	......	83	......	......	......	......	......	......	......	......	......	......	......
326	......	......	80	......	......	......	......	......	......	......	......	......	......	......
327	......	......	67	......	......	......	......	......	......	......	......	......	......	......
328	......	......	51	......	......	......	......	......	......	......	......	......	......	......
Average.	8.6	8.5	67.4	25.4	90.7	1.4	......	......	......	......	......	......	......	10.8
1910:														
122	19.3	8.8	76	35	111	54.6	82.0	4.7	49.4	24.9	50.4	2,726	1,346	11.7
123	12.8	6.6	80	31	111	48.5	70.5	4.7	31.6	12.0	38.0	3,145	995	6.5
171	16.9	8.0	61	36	97	52.5	100.0	5.5	59.3	38.0	64.0	2,600	1,543	17.0
171	11.6	6.2	61	36	97	46.6	100.0	4.7	55.5	36.0	64.9	2,699	1,499	16.8
171–9	33.1	19.2	78	25	103	41.9	[a]117.4	4.7	49.4	27.4	55.4	2,010	993	9.5
193	41.0	17.4	75	36	111	57.6	94.5	4.5	59.4	33.0	56.0	1,736	1,031	10.0
261	43.4	23.9	56	36	92	44.9	[a]106.8	5.2	46.8	25.1	53.6	1,424	666	6.2
293	13.9	8.5	80	31	111	39.1	69.2	2.7	50.5	18.3	38.1	2,102	1,062	6.6
309	37.0	11.8	77	40	117	68.2	95.8	5.5	65.1	33.7	51.6	2,494	1,624	14.5
309	42.1	12.0	77	40	117	71.4	96.8	5.0	62.5	36.7	58.7	2,460	1,537	15.6
324	15.8	6.0	90	21	111	62.1	63.3	4.7	49.2	26.5	54.6	......	......	6.5
326	10.2	3.9	90	23	113	61.3	43.2	6.0	......	......	......	......	......	5.8
327	14.4	5.7	78	33	113	60.6	82.1	7.0	......	......	......	......	......	8.2
328	24.7	15.8	60	26	86	36.2	[a]102.8	5.2	......	......	......	1,630	793	7.5
413	27.3	19.3	92	21	113	29.3	91.5	5.8	......	......	......	......	......	10.6
414	25.6	7.3	89	40	129	71.5	84.2	6.7	......	......	......	......	......	8.3
421	11.2	5.7	80	28	108	49.0	92.0	6.0	......	......	......	......	......	14.3
423	22.0	13.5	83	34	117	38.5	76.1	7.0	......	......	......	......	......	6.3
424	26.9	16.6	80	28	108	38.5	88.5	6.0	......	......	......	......	......	14.2
Average.	23.6	11.4	77	31.5	108.6	51.1	87.2	5.3	52.6	28.3	53.2	2,275	1,189	10.3

[a] Includes mature heads on branches.

TABLE XXXIV.—*Agronomic data for Brown kaoliang grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive*—Continued.

Year and C. I. No.	Row space.		Length of period.			Suckers.	Headed.	Height of plants.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
1911:	*Ins.*	*Ins.*	*Days.*	*Days.*	*Days.*	*P.ct.*	*P.ct.*	*Feet.*	*P.ct.*	*P.ct.*	*P.ct.*	*Lbs.*	*Lbs.*	*Bus.*
123	11.0	7.4	72	37	109	33.1	......	7.0	57.3	36.6	64.2	4,330	2,485	27.5
193	11.4	10.8	66	30	96	5.3	......	5.8	56.3	37.4	66.5	3,880	2,185	25.1
171	7.1	5.7	66	29	95	19.2	......	6.5	56.9	35.7	62.6	4,760	2,710	29.3
261	8.7	7.7	63	29	92	11.6	......	6.5	45.1	27.7	61.4	3,856	1,740	18.4
261	8.9	7.7	63	29	92	13.0	......	6.5	44.5	26.6	60.4	3,356	1,496	15.6
328	5.8	5.5	60	31	91	5.1	......	5.6	52.0	28.9	55.6	3,830	1,995	19.2
328	6.2	5.9	61	30	91	3.6	......	6.5	51.9	37.7	72.7	3,610	1,875	23.5
324	4.3	3.5	73	37	110	18.4	......	5.5	45.1	24.5	54.3	5,035	2,275	21.3
326	4.8	3.9	85	25	110	17.7	......	6.5	33.6	19.3	57.5	5,635	1,895	18.8
327	6.6	5.4	71	25	96	17.9	......	8.0	46.0	28.4	61.2	4,031	1,856	19.8
376	20.0	6.5	92	18	110	67.5	......	6.3	18.2	5.1	28.0	5,875	1,075	5.2
277	10.7	4.2	92	18	110	60.7	......	5.5	37.2	15.0	40.0	5,262	1,962	13.7
278	7.3	4.2	83	27	110	42.7	......	7.0	46.5	21.9	47.0	5,987	2,787	22.6
122	8.1	7.1	71	30	101	12.3	......	5.8	56.4	35.6	63.7	4,364	2,454	26.9
293	9.6	8.3	71	30	101	13.8	......	3.5	65.2	40.8	62.6	3,917	2,557	27.6
309	11.9	6.2	71	41	112	47.5	......	6.5	58.9	35.6	60.3	5,047	2,977	31.0
413	10.5	7.3	71	27	98	30.6	......	6.0	40.4	31.0	76.7	4,956	2,006	26.5
414	9.1	4.3	83	36	119	52.5	......	8.0	29.5	13.9	47.2	7,025	2,075	16.9
421	8.3	4.5	68	44	112	45.4	......	6.3	61.0	29.6	48.6	4,493	2,743	22.9
423	7.5	6.8	68	42	110	9.3	......	8.0	51.3	30.0	58.4	4,725	2,425	24.4
424	5.7	5.1	68	28	96	10.2	......	6.3	55.8	32.6	58.3	4,984	2,784	28.0
Average	8.7	6.1	72	30.6	102.9	25.6	......	6.3	48.0	28.2	57.4	4,712	2,207	22.1
1912:														
123	4.9	4.5	84	37	121	7.1	72.6	5.0	30.8	12.8	40.0	4,340	1,340	9.3
193	5.9	5.7	76	22	98	3.7	96.2	4.5	33.9	18.2	53.6	4,860	1,650	15.3
171	3.0	2.9	73	25	98	3.3	96.2	5.0	44.7	25.4	56.9	4,430	1,983	19.5
261	4.1	4.0	66	28	94	2.1	98.0	4.3	47.6	28.3	59.5	3,340	1,590	16.3
328-1	5.4	5.3	57	34	91	1.0	98.9	4.0	56.1	33.6	59.6	2,600	1,460	15.1
328-2	5.3	5.3	57	34	91	......	98.3	4.0	56.9	35.7	62.9	2,380	1,355	14.7
328	3.9	3.9	67	27	94	......	98.3	4.3	51.1	29.9	58.5	3,030	1,550	15.6
324	5.2	4.0	87	34	121	23.2	66.0	4.8	38.1	16.0	42.0	4,540	1,730	12.5
326	2.9	2.6	94	28	122	8.2	39.2	6.0	16.5	6.0	36.3	5,180	855	5.4
327	2.2	2.1	87	28	115	4.4	61.2	7.0	27.1	8.6	31.7	4,000	1,088	6.0
276	7.0	3.6	104	25	129	48.8	6.6	5.8	2.2	.7	31.9	5,269	119	.7
277	8.1	3.1	104	25	129	61.9	8.7	5.0	4.5	1.2	28.6	4,820	219	1.1
278	2.1	2.0	118	34	152	4.6	61.4	6.0	28.9	10.0	34.7	5,600	1,619	9.7
122	4.1	3.8	84	37	121	6.4	89.6	5.0	35.9	13.3	37.0	4,480	1,610	10.3
293	3.9	3.8	87	34	121	2.1	87.2	3.0	29.6	8.8	29.8	3,380	1,003	5.2
309	4.0	3.6	87	34	121	8.6	76.7	4.8	33.9	16.1	47.5	4,010	1,360	11.2
413	5.7	4.7	87	28	115	17.6	79.6	5.0	29.4	11.4	38.7	4,460	1,313	8.8
414	4.0	3.6	94	30	124	8.4	44.7	6.0	10.8	5.8	53.7	4,746	512	4.7
421	4.8	3.1	76	28	104	34.6	92.2	4.5	50.1	26.9	53.7	3,900	1,958	18.1
423	3.7	3.6	76	28	104	3.7	94.5	5.5	44.4	25.8	58.3	4,475	1,988	20.0
424	3.9	3.6	71	27	98	6.0	94.9	4.5	50.5	31.0	61.4	4,760	2,408	25.5
475	39.6	22.3	71	33	104	43.6	61.4	5.5	58.8	39.4	67.0	1,700	1,000	12.8
Average	6.1	4.6	82	30	112	13.6	73.7	4.9	35.5	18.4	47.4	4,104	1,350	11.7
1913:														
123	8.0	7.2	72	30	102	10.0	......	3.0	......	......	......	......	......	......
193	12.1	11.4	64	29	93	5.2	......	3.5	......	......	......	......	......	......
171	7.0	6.7	64	30	94	4.4	......	3.5	......	......	......	......	......	......
261	4.3	4.2	64	38	92	2.8	......	3.5	......	......	......	......	......	......
328	4.4	4.3	56	36	92	.8	......	3.5	......	......	......	......	......	......
328-1	3.4	3.4	53	34	87	.3	......	3.5	......	......	......	......	......	......
328-2	3.7	3.6	53	34	87	.2	......	3.5	......	......	......	......	......	......
324	3.5	3.1	74	28	102	9.5	......	3.0	......	......	......	......	......	......
326	3.6	3.2	87	......	......	11.1	......	3.0	......	......	......	......	......	......
327	8.1	6.4	71	31	102	20.5	......	4.5	......	......	......	......	......	......
276	4.8	3.5	......	......	......	27.9	......	2.5	......	......	......	......	......	......
277	3.9	2.8	......	......	......	27.0	......	2.5	......	......	......	......	......	......
278	3.1	2.8	75	27	102	7.5	......	3.0	......	......	......	......	......	......
122	5.3	5.1	75	27	102	5.0	......	3.0	......	......	......	......	......	......
293	4.3	4.3	75	27	102	2.2	......	2.5	......	......	......	......	......	......
309	5.4	4.7	70	25	95	14.3	......	3.0	......	......	......	......	......	......
413	6.5	5.9	71	24	95	8.7	......	3.0	......	......	......	......	......	......
414	3.4	2.9	101	......	......	4.0	......	3.0	......	......	......	......	......	......
421	2.4	2.3	71	24	95	4.2	......	3.0	......	......	......	......	......	......
423	4.5	4.2	71	31	102	5.1	......	3.0	......	......	......	......	......	......
424	4.3	4.1	64	28	92	4.5	......	3.0	......	......	......	......	......	......
475	3.8	3.6	64	28	92	4.4	......	3.5	......	......	......	......	......	......
503	3.8	3.7	71	24	95	29.2	......	3.0	......	......	......	......	......	......
Average	4.9	4.5	69	28	97	9.5	......	3.1	......	......	......	......	......	......

TABLE XXXIV.—*Agronomic data for Brown kaoliang grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive*—Continued.

Year and C. I. No.	Row space.		Length of period.			Suckers.	Headed.	Height of plants.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
1914:	*Ins.*	*Ins.*	*Days.*	*Days.*	*Days.*	*P.ct.*	*P.ct.*	*Feet.*	*P.ct.*	*P.ct.*	*P.ct.*	*Lbs.*	*Lbs.*	*Bus.*
171	6.5	5.1	60	20	80	21.9	97.5	5.3	57.5	35.1	61.0	3,300	1,900	20.0
261	3.2	3.2	53	20	73	.8	94.1	5.5	58.7	30.7	52.3	2,860	1,680	15.2
328	3.2	3.1	52	22	74	.4	94.5	5.8	66.9	31.7	47.5	2,900	1,940	15.9
328-1	3.1	3.1	51	21	72	.0	97.3	5.8	68.6	37.3	54.4	3,000	2,060	19.3
324	2.0	1.9	71	25	96	.5	34.3	4.0	25.3	9.5	37.6	5,440	1,380	9.0
293	4.0	3.9	64	32	96	.3	64.3	3.0	......	25.9	......	2,780	......	12.4
413	4.0	3.9	60	29	89	.3	77.9	4.8	50.9	28.0	55.0	4,280	2,180	20.7
421	3.6	2.5	58	27	85	.3	66.2	4.5	50.8	24.5	48.2	3,800	1,933	16.0
423	3.4	3.4	58	29	87	1.0	68.5	5.8	57.1	31.7	55.5	3,150	1,800	17.2
424	2.2	2.1	56	29	85	.2	81.9	5.3	47.0	24.0	51.0	5,000	2,350	20.7
475	4.1	4.2	56	29	85	.6	79.5	5.3	52.0	30.6	58.8	3,166	1,700	17.2
Average.	3.5	3.3	58	25.7	83.8	2.4	77.8	5.0	48.6	28.0	47.4	3,606	1,892	16.7
1915:														
171	4.0	3.8	67	36	103	4.3	92.9	6.5	......	......	......	......	......	46.6
261	4.7	4.2	62	32	94	9.4	92.1	6.5	......	......	......	......	......	29.0
328	7.6	7.1	62	32	94	6.7	96.6	6.5	......	......	......	......	......	24.8
328-1	6.5	6.3	56	38	94	2.3	98.5	5.8	......	......	......	......	......	21.5
324	4.7	4.2	76	43	119	10.7	92.7	5.0	42.3	26.1	61.7	7,800	3,300	35.2
293	7.2	6.9	71	39	110	3.8	96.7	3.8	57.3	38.8	67.8	5,760	3,300	38.6
413	6.8	5.3	71	48	119	21.6	97.0	5.5	......	......	......	......	......	48.6
424	4.7	4.4	67	52	119	5.8	100.0	5.5	......	......	......	......	......	38.9
Average.	5.8	5.3	66	40	106	8.1	95.8	5.6	......	......	......	......	......	35.4
1916:														
171	25.5	17.7	70	27	97	30.8	86.2	4.0	......	35.1	......	1,080	......	6.6
261	9.9	8.3	59	23	82	15.7	65.5	3.3	......	34.8	......	920	......	5.5
328	13.6	10.9	58	30	88	19.7	73.6	3.0	......	35.7	......	840	......	5.2
328-1	13.0	11.4	57	24	81	12.4	78.7	3.3	......	35.7	......	560	......	3.4
324	10.0	6.3	84	51	135	37.1	45.2	3.5	......	10.0	......	2,400	......	4.1
293	16.2	13.1	84	51	135	19.1	42.2	2.3	......	8.6	......	1,160	......	1.7
413	13.0	8.6	83	35	118	33.5	39.1	3.5	......	8.1	......	1,980	......	2.7
424	17.8	13.1	75	43	118	26.4	73.7	3.8	......	18.7	......	960	......	3.1
Average.	14.9	11.2	71.2	35.5	106.7	24.3	63.0	3.4	......	23.3	......	1,237	......	4.0

Manchu kaoliang does not tiller as freely as most of the grain sorghums. The largest percentage of suckers produced was 49.5 per cent, in 1910, when the plant space was 14.2 inches. This was one sucker to each main stalk and reduced the stalk space to 7.1 inches. The average height of this variety has been 5.1 feet and the variation from 3.5 feet, in 1913, to 6.5 feet, in 1911 and 1915.

The annual and average acre yields of leading Brown kaoliangs are brought together in Table XXXV, and the acre yields of the leading varieties in all three subgroups are compared in Table XXXVI. The 9-year average acre yield of Manchu kaoliang has been 21.2 bushels. This exceeds the yield of any of the kafirs or White durra, but falls just below those of Alba milo and feterita. It is about 3 bushels below the average yield of milo and about 7 bushels below that of Dwarf milo. Although this kaoliang failed completely in 1913, as did all the grain sorghums, it has given better yields in the other dry years than most of the varieties. In 1916 its yield was 6.6

bushels. The next lowest yield was 16.9 bushels, in 1910, a very dry year. In 1915, the most favorable season of all, however, its yield was only 46.6 bushels per acre, which was 15 to 20 bushels lower than those of some of the best varieties in other grain-sorghum groups.

TABLE XXXV.—*Annual and average acre yields of Brown kaoliangs grown at the Amarillo Cereal Field Station during periods of varying length in the nine years from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

Variety.	C. I. No.	Annual and average acre yield (bushels).												
		1908	1909	1910	1911	1912	1913	1914	1915	1916	4 years, 1910 to 1913.	6 years, 1908 to 1913.	7 years, 1910 to 1916.	9 years, 1908 to 1916.
Peesan	122	33.9	14.4	11.7	26.9	10.3	0	......	......	......	12.2	16.2	......	......
Tientsin	123	31.3	9.9	6.5	27.5	9.3	0	......	......	......	10.8	14.1	......	......
Manchu	171	[a]33.4	[a]18.1	17.0	29.3	19.5	0	20.0	46.6	6.6	16.5	19.6	19.9	21.2
Kali	193	26.3	12.8	10.0	25.1	15.3	0	......	......	......	12.6	14.9	......	......
Manchu	261	20.9	11.4	6.2	18.4	16.3	0	15.2	29.0	5.5	10.2	12.2	12.9	13.7
Shantung	293	33.6	3.5	6.6	27.6	5.2	0	12.4	38.6	1.7	9.9	12.8	13.2	14.4
Valley	309	37.4	16.0	14.5	31.0	11.2	0	......	......	......	14.2	18.4	......	......
Chusan	324	......	......	6.5	21.3	12.5	0	9.0	35.2	4.1	10.1	......	12.7	......
Hankow	326	......	......	5.8	18.8	5.4	0	......	......	......	7.5	......	......	......
Redstem	327	......	......	8.2	19.8	6.0	0	......	......	......	8.5	......	......	......
Manchu	328	......	......	7.5	19.2	15.6	0	15.9	24.8	5.2	10.6	......	12.6	......
Choonchun	413	......	......	10.6	26.5	8.8	0	20.7	48.6	2.7	11.5	......	16.8	......
Moose	414	......	......	8.3	16.9	4.7	0	......	......	......	7.5	......	......	......
Ware	421	......	......	14.3	22.9	18.1	0	16.0	......	......	13.8	......	......	......
Valley	423	......	......	6.3	24.4	20.0	0	17.2	......	......	12.7	......	......	......
Parker	424	......	......	14.2	28.0	25.5	0	20.7	38.9	3.1	16.9	......	18.6	......

[a] Average of three plats.

Two other races of Manchu kaoliang almost identical with C. I. No. 171 are C. I. Nos. 261 and 328. Of these, No. 261 has been grown throughout the whole nine years. It is usually from three to five days earlier than No. 171, but seldom germinates to as good a stand and does not yield as well. The 9-year average acre yield of C. I. No. 261 is only 13.5 bushels, while that of C. I. No. 171 is 21.2 bushels, or 7.7 bushels more. C. I. No. 328 was first grown in 1910. It is of about the same earliness as No. 261 and usually had about the same stand or a little poorer than that of No. 171. Its average acre yield in the 7-year period was 12.9 bushels and that of No. 261 was 12.7 bushels, while that of No. 171 was 19.8 bushels. In the same seven years Shantung, No. 293, a very dwarf but stocky and later variety, produced 13.2 bushels. It is evident that while earlier in maturing, neither No. 261 nor No. 328 can compete with No. 171 in yield. No. 261 yielded 12.5 bushels less than No. 171 in 1908, a good year, and 17.6 less in 1915, a year of bumper yields, in which No. 328 yielded 21.8 bushels less than No. 171.

Another selection, C. I. No. 324, which is two to three weeks later than C. I. No. 171, has been grown during the last seven years. It was thought to be promising, but its average acre yield in that time has been only 12.7 bushels, exactly the same as that of C. I. No. 261. In addition, it was able to make a yield of only 35.2 bushels in 1915, so it may be dropped from further consideration.

The two selections, C. I. Nos. 413 and 424, are fairly promising. They are about 10 days later than C. I. No. 171, but about equal to it in height. Both have been grown only during the last seven years, and their average acre yields in that time have been 16.8 and 18.6 bushels, respectively. The yield of No. 171 was 19.8 bushels in the same period, or 1.2 bushels more than that of No. 424. In 1915 the yield of No. 413 was 48.6 bushels and that of No. 424 was 38.9 bushels, the former exceeding the yield of No. 171 by 2 bushels in that year. Valley, C. I. No. 309, a variety about two weeks later and a little taller than No. 171, was grown during the first six years and produced an average acre yield of 18.4 bushels compared with 19.5 bushels from No. 171 in the same years. Nos. 261 and 293 yielded in the same years 12 and 12.7 bushels, respectively.

COMPARATIVE YIELDS OF ALL THE KAOLIANGS.

A survey of the comparative yields given in Table XXXVI shows that varieties of the brown-seeded kaoliangs have made the best average yields in both the 7-year and 9-year periods. In the 7-year period three brown-seeded sorts outyield the Barchet (blackhull), which in turn outyields the Mukden (white). In the 9-year period two of the high-yielding brown-kerneled sorts are not present, but the other three varieties maintain the same relative rank as before.

TABLE XXXVI.—*Annual and average acre yields of grain of the leading varieties and races in each of the subgroups of the kaoliang group of grain sorghums grown at the Amarillo Cereal Field Station in most or all of the nine years from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

Subgroup and variety.	C. I. No.	Annual yields (bushels).									Average yields.		
		1908	1909	1910	1911	1912	1913	1914	1915	1916	7 years, 1910 to 1916.	9 years, 1908 to 1916.	
White:											*Bus.*	*Bus.*	*Cwt.*
Mukden	190	......	12.8	12.2	25.1	8.4	0	14.9	13.8	3.4	11.1	......	......
Blackhull:													
Barchet	310	43.1	9.4	8.6	30.7	14.4	0	6.2	45.8	3.4	15.6	18.0	10.4
Brown:													
Manchu	171	33.4	18.1	17.0	29.3	19.5	0	20.0	46.6	6.6	19.9	21.2	12.3
	261	20.9	11.4	6.2	18.4	16.3	0	15.2	29.0	5.5	12.9	13.7	7.9
	328	......	......	7.5	19.2	15.6	0	15.9	24.8	5.2	12.6	......	......
Shantung	293	33.6	3.5	6.6	27.6	5.2	0	12.4	38.6	1.7	13.2	14.4	8.4
Chusan	324	......	......	6.5	21.3	12.5	0	9.0	35.2	4.1	12.7	......	......
Choonchun	413	......	......	10.6	26.5	8.8	0	20.7	48.6	2.7	16.8	......	......
Parker	424	......	......	14.2	28.0	25.5	0	20.7	38.9	3.1	18.6	......	......

THE SHALLU GROUP.

Shallu was introduced from India about 25 years ago and first grown in Louisiana. From there it was carried westward to Texas, where it is still sparingly grown. In the past 10 years it has been widely exploited[1] under fanciful and misleading names, such as "California Wheat," "Egyptian Wheat," "Old Mexico Desert Wheat-corn," etc.

TABLE XXXVII.—*Agronomic data for shallu grown at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 58 pounds.]

Year and C. I. No.	Row space.		Length of period.			Suckers.	Headed.	Height of plants.	Heads in crop.	Seed in—		Yields per acre.		
	Plants.	Stalks.	Vegetating.	Fruiting.	Total growing.					Crop.	Heads.	Total crop.	Heads.	Seed.
	Ins.	*Ins.*	*Days.*	*Days.*	*Days.*	*P. ct.*	*P. ct.*	*Feet.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Bus.*
1908:														
85	10.1	3.8	78	......	......	62.3	......	6.0	......	......	......	......	......	......
125	......	......	78	......	......	......	......	6.0	......	......	......	......	......	......
217	10.5	3.7	78	......	......	64.7	......	6.0	......	......	......	......	......	......
Average	10.3	3.2	78	......	......	63.5	......	6.0	......	......	......	......	......	......
1910:														
85	102.2	14.4	[a] 91	35	126	84.5	......	6.0	......	......	......	......	......	......
125	24.6	5.9	[a] 91	34	125	76.1	......	6.0	......	......	......	......	......	......
165	24.4	6.2	[a] 97	29	126	74.5	......	6.0	......	......	......	......	......	......
217	30.2	7.2	[a] 97	29	126	80.8	......	6.0	......	......	......	......	......	......
349	19.9	4.7	[a] 97	29	126	76.3	......	6.5	......	......	......	......	......	......
383	54.6	12.4	[a] 61	51	128	77.2	64.0	5.7	......	......	......	......	......	......
387	33.7	17.0	[a] 91	51	142	49.5	66.7	5.5	......	......	......	......	......	......
380	23.3	5.7	......	......	......	75.7	......	......	......	......	......	......	......	......
Average	39.1	9.2	89	36.8	128.4	74.3	65.3	5.2	......	......	......	......	......	......
1911:														
85	......	......	87	38	125	......	......	5.5	60.3	25.9	42.9	2,525	1,525	8.9
125	......	......	87	38	125	......	......	6.0	56.7	31.4	55.4	4,856	2,756	26.3
217	......	......	87	38	125	......	......	6.0	45.4	23.1	48.4	2,293	1,093	9.1
349	......	......	87	38	125	......	......	6.0	50.9	27.8	54.6	5,093	2,593	24.4
Average	......	......	87	38	125	......	......	5.8	53.3	27.0	50.3	3,692	1,992	17.2
1912:														
85	16.2	3.4	96	35	131	79.0	15.4	4.0	9.0	5.5	61.2	4,070	370	3.9
125	15.6	3.5	96	35	131	77.5	22.1	4.0	14.3	8.8	62.1	4,108	588	6.6
165	31.7	6.2	96	35	131	80.4	40.2	4.0	21.1	12.2	57.6	3,425	725	7.2
217	20.0	4.4	96	35	131	77.9	35.1	4.3	16.9	9.8	58.0	4,553	773	7.7
349	20.8	4.7	96	35	131	77.3	46.3	4.3	18.3	10.8	59.3	5,435	995	10.2
387	105.6	18.2	96	35	131	71.2	60.9	4.0	28.4	11.4	40.1	1,538	438	3.0
Average	34.9	6.7	96	35	131	77.2	36.6	4.1	18.0	9.7	56.4	3,855	648	6.4
1913:														
85	7.2	3.6	......	......	......	49.2	......	2.0	......	......	......	......	......	......
125	13.9	6.6	......	......	......	54.1	......	2.0	......	......	......	......	......	......
165	8.0	4.2	......	......	......	47.8	......	2.0	......	......	......	......	......	......
217	8.4	4.5	......	......	......	51.5	......	2.0	......	......	......	......	......	......
349	9.5	4.7	......	......	......	50.3	......	2.0	......	......	......	......	......	......
387	17.6	7.3	......	......	......	58.8	......	2.0	......	......	......	......	......	......
Average	10.7	5.1	......	......	......	51.9	......	2.0	......	......	......	......	......	......
1914:														
85	4.8	2.9	66	50	116	39.0	6.5	4.0	4.8	3.4	70.0	4,100	200	2.1
1915:														
85	12.6	5.2	88	55	143	59.2	......	8.0	......	......			......	34.5
1916:														
85	19.0	6.7	133	......	......	64.9	......	3.5	......	......	......	......	......	......

[a] First and only heads.

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[1] Ball, C. R. Three much-misrepresented sorghums. U. S. Dept. Agr., Bur. Plant Indus. Cir. 50, 14 p., 2 fig. 1910.

Rothgeb, B. E. Shallu, or "Egyptian wheat": A late-maturing variety of sorghum. U. S. Dept. Agr., Farmers' Bul. 827, 8 p., 2 fig. 1917.

It has been grown at Amarillo in all the nine years except 1909. The data resulting are presented in Table XXXVII. It has proved itself quite unfitted for the dry-land conditions obtaining in the Texas Panhandle, as is fully shown also in the publications cited. Its germination has been poor in nearly all years. It is tall and very late in maturing, frequently lodging in autumn storms and often failing to ripen. For these reasons the yields have been very low. In 1910, 1913, and 1916 it produced no grain at all. The production of suckers has always been high, and where adapted it is more likely to prove of value for forage than for grain

COMPARATIVE YIELDS OF ALL THE GROUPS.

The annual and average acre yields of the leading races in each variety of each group of grain sorghums are shown in Table XXXVIII. The average yields are given first for the 7-year period, from 1910 to 1916, inclusive, in order to compare a few selections grown only in those years. The average yields in the full 9-year period from 1908 to 1916, inclusive, are given for all selections grown that long.

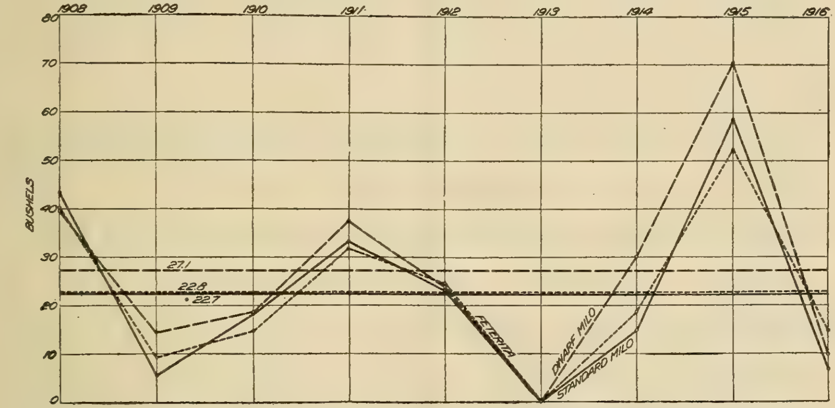

FIG. 12.—Diagram showing the annual and average acre yields, in 58-pound bushels, of standard milo, Dwarf milo, and feterita at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive.

It will be noted from this table that Dwarf milo made the highest average yield of any subgroup in both the 7-year and the 9-year periods. Therefore it takes first place in grain production among the grain-sorghum groups. The best selection of Dwarf milo yielded an average of 27.2 bushels annually in the 7-year period and 27.1 bushels in the 9-year period. The average yield of Dwarf milo in both periods is approximately 5 bushels more than the average yield of any other variety. Figure 12 shows graphically the annual and average yields of milo, Dwarf milo, and feterita in the 9-year period from 1908 to 1916, inclusive, at Amarillo, Tex.

Milo, Alba milo, feterita, and Manchu kaoliang have average yields ranging from about 20 to 22 bushels in the 7-year period and from about 21 to 23 bushels in the 9-year period. These four varieties may be said to tie for second place in grain production. There is little choice between them except when their combined grain and fodder value is considered. Manchu kaoliang has less fodder value than the milos or feterita because of its drier and more slender stems and scanty foliage.

TABLE XXXVIII.—*Annual and average acre yields of the best selections in all varieties and groups of grain sorghums grown at the Amarillo Cereal Field Station in most or all of the nine years from 1908 to 1916, inclusive.*

[In the statement of yields per acre the bushel is rated at 60 pounds for kafirs and at 58 pounds for all other sorghums.]

Group and variety.	C. I. No.	Annual and average acre yields (bushels).										
		1908	1909	1910	1911	1912	1913	1914	1915	1916	7 years, 1910 to 1916.	9 years, 1908 to 1916.
Milo-durra:												
Milo	223	37.4	16.5	18.8	24.4	23.6	0	12.8	64.8	7.6	21.7	22.9
Do	232	30.4	3.6	9.8	30.1	33.0	0	10.7	60.0	6.6	21.5	20.5
Do	234	43.2	5.8	18.2	33.3	23.3	0	14.8	58.6	6.9	22.2	22.7
Dwarf milo	149	42.6	12.4	20.8	36.8	13.3	0	30.0	74.1	7.6	26.1	26.4
Do	332	39.5	14.2	18.6	37.4	24.0	0	30.0	70.3	9.7	27.2	27.1
Do	359	......	......	20.0	37.3	34.6	0	16.2	68.3	8.6	26.4	......
Alba milo	352	......	......	16.9	37.5	15.8	0	11.4	59.3	4.8	20.8	......
Feterita	182	40.2	9.3	14.7	31.9	24.5	0	18.5	52.1	14.5	22.3	22.8
White durra	81	35.7	7.7	10.0	26.4	24.3	0	22.4	36.9	4.5	17.8	18.7
Durra-kafir hybrids:												
Black glumed	198-7-3	41.0	2.8	9.1	30.2	3.0	0	16.2	34.5	7.2	14.3	16.0
Do	198-15-3	27.4	7.8	5.4	39.9	4.1	0	20.7	24.5	2.4	13.9	14.7
White glumed	198-7-3	41.0	2.8	21.2	28.2	6.0	0	13.8	28.1	5.7	14.7	16.3
Do	198-15-3	27.4	7.8	16.0	34.1	11.6	0	14.8	17.9	1.7	13.7	14.6
Do	240	35.7	4.2	17.0	46.1	5.0	0	8.6	29.3	3.5	15.6	16.6
Do	240-6	35.7	4.2	17.0	30.3	11.5	0	19.3	36.2	3.5	16.8	17.5
Kafir:												
Blackhull	71	42.2	3.5	1.0	26.5	4.7	0	14.0	64.0	0	15.7	17.3
Do	335	37.0	10.7	4.8	20.6	4.6	0	11.3	62.7	0	14.9	16.9
Do	337	38.3	7.7	3.5	21.0	4.7	0	9.3	64.0	0	14.6	16.5
Sunrise	472	......	10.8	7.6	21.4	8.0	0	10.4	56.0	9.3	17.5	......
Dawn (dwarf)	340	29.0	14.4	9.3	34.9	9.6	0	14.7	53.3	3.7	17.9	18.8
White	370	......	......	8.8	23.7	13.5	0	14.3	37.3	4.0	14.5	......
Red	34	36.4	4.0	5.2	18.7	3.0	0	13.3	44.3	0	12.1	13.9
Do	356	......	......	7.5	24.3	11.2	0	15.8	57.0	0	16.5	......
New	316	......	4.3	0	40.0	4.7	0	12.7	66.0	0	17.6	......
Do	314	......	9.6	5.7	25.2	11.8	0	6.0	46.7	0	13.6	......
Kaoliang:												
Mukden	190	......	12.8	12.2	25.1	8.4	0	14.9	13.8	3.4	11.1	......
Barchet	310	43.1	9.4	8.6	30.7	14.4	0	6.2	45.8	3.4	15.6	18.0
Manchu	171	33.4	18.1	17.0	29.3	19.5	0	20.0	46.6	6.6	19.9	21.2
Shantung	293	33.6	3.5	6.6	27.6	5.2	0	12.4	38.6	1.7	13.2	14.4
Parker	424	......	......	14.2	28.0	25.5	0	20.7	38.9	3.1	18.6	......

The best varieties in the kafir group take third place in grain production under Panhandle conditions. Dawn (dwarf) kafir and Sunrise kafir lead with average yields of 17.9 and 17.5 bushels, respectively, in the 7-year period. Dawn kafir, with an average acre yield of 18.8 bushels in the 9-year period, leads by more than 1 bushel over its nearest competitor. The kafirs have a higher value as combined grain and fodder crops than any other grain sorghums. In actual farm value, therefore, Dawn kafir and Sunrise kafir should be given second place, taking precedence over milo and feterita. Figure 13 shows graphically the annual and average yields of Blackhull kafir, Dawn kafir, and Red kafir in the 9-year period from 1908 to 1916, inclusive, at Amarillo, Tex.

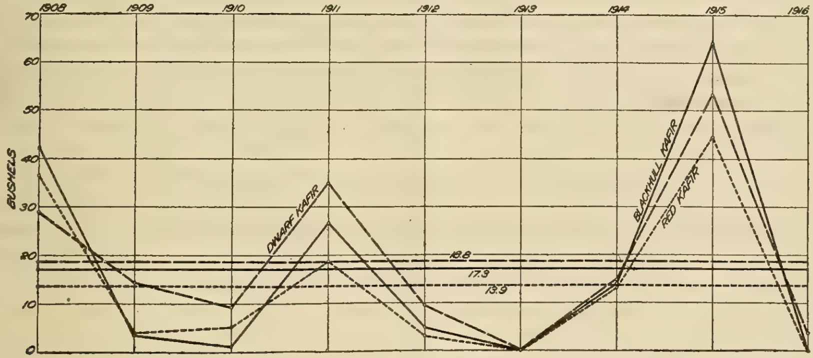

FIG. 13.—Diagram showing the annual and average acre yields, in 60-pound bushels, of Blackhull kafir, Dawn (dwarf) kafir, and Red kafir at the Amarillo Cereal Field Station during the 9-year period from 1908 to 1916, inclusive.

CONCLUSIONS.

The data presented in this bulletin warrant the following conclusions:

(1) Many varieties produce well in favorable seasons. Only well-adapted varieties produce well in the less favorable and unfavorable seasons, which comprise about three-quarters of the total number.

(2) Earliness is the most important single factor in the varietal adaptation of grain-sorghum crops to the conditions obtaining in the high plains of the Texas Panhandle.

(3) Dwarfness is the next most important factor in the adaptation of these crops.

(4) The combination of earliness and dwarfness is extremely efficient in insuring adaptation to environmental conditions which include frequent periods of drought.

(5) Dwarf milo, Dawn (dwarf) kafir, and Sunrise (early) kafir are shown to be well-adapted varieties.

(6) Dwarf milo and Dawn kafir are meeting with wide approval on the farms of the high, dry plains.

(7) Germination and stand are governed largely by local conditions at sowing time.

(8) Tillering, or the production of suckers, is a varietal or group character to some extent. In part it is correlated with stand and seasonal conditions.

(9) The production of erect heads is largely a group or varietal character, but is influenced by the same factors as tillering.

THE PRESIDENT TO THE FARMERS OF AMERICA.

[Extracts from President Wilson's message to the Farmers' Conference at Urbana, Ill., Jan. 31, 1918.]

"The forces that fight for freedom, the freedom of men all over the world as well as our own, depend upon us in an extraordinary and unexpected degree for sustenance, for the supply of the materials by which men are to live and to fight, and it will be our glory when the war is over that we have supplied those materials and supplied them abundantly, and it will be all the more glory because in supplying them we have made our supreme effort and sacrifice.

"In the field of agriculture we have agencies and instrumentalities, fortunately, such as no other government in the world can show. The Department of Agriculture is undoubtedly the greatest practical and scientific agricultural organization in the world. Its total annual budget of $46,000,000 has been increased during the last four years more than 72 per cent. It has a staff of 18,000, including a large number of highly trained experts, and alongside of it stand the unique land-grant colleges, which are without example elsewhere, and the 69 State and Federal experiment stations. These colleges and experiment stations have a total endowment of plant and equipment of $172,000,000 and an income of more than $35,000,000, with 10,271 teachers, a resident student body of 125,000, and a vast additional number receiving instruction at their homes. County agents, joint officers of the Department of Agriculture and of the colleges, are everywhere cooperating with the farmers and assisting them. The number of extension workers under the Smith-Lever Act and under the recent emergency legislation has grown to 5,500 men and women working regularly in the various communities and taking to the farmer the latest scientific and practical information. Alongside these great public agencies stand the very effective voluntary organizations among the farmers themselves which are more and more learning the best methods of cooperation and the best methods of putting to practical use the assistance derived from governmental sources. The banking legislation of the last two or three years has given the farmers access to the great lendable capital of the country, and it has become the duty both of the men in charge of the Federal-reserve banking system and of the farm-loan banking system to see to it that the farmers obtain the credit, both short term and long term, to which they are entitled not only, but which it is imperatively necessary should be extended to them if the present tasks of the country are to be adequately performed. Both by direct purchase of nitrates and by the establishment of plants to produce nitrates, the Government is doing its utmost to assist in the problem of fertilization. The Department of Agriculture and other agencies are actively assisting the farmers to locate, safeguard, and secure at cost an adequate supply of sound seed.

"The farmers of this country are as efficient as any other farmers in the world. They do not produce more per acre than the farmers in Europe. It is not necessary that they should do so. It would perhaps be bad economy for them to attempt it. But they do produce by two to three or four times more per man, per unit of labor and capital, than the farmers of any European country. They are more alert and use more labor-saving devices than any other farmers in the world. And their response to the demands of the present emergency has been in every way remarkable. Last spring [1917] their planting exceeded by 12,000,000 acres the largest planting of any previous year, and the yields from the crops were record-breaking yields. In the fall of 1917 a wheat acreage of 42,170,000 was planted, which was 1,000,000 larger than for any preceding year, 3,000,000 greater than the next largest, and 7,000,000 greater than the preceding five-year average.

"But I ought to say to you that it is not only necessary that these achievements should be repeated, but that they should be exceeded. I know what this advice involves. It involves not only labor, but sacrifice, the painstaking application of every bit of scientific knowledge and every tested practice that is available. It means the utmost economy, even to the point where the pinch comes. It means the kind of concentration and self-sacrifice which is involved in the field of battle itself, where the object always looms greater than the individual. And yet the Government will help and help in every way that is possible.

"It was farmers from whom came the first shots at Lexington, that set aflame the Revolution that made America free. I hope and believe that the farmers of America will willingly and conspicuously stand by to win this war also. The toil, the intelligence, the energy, the foresight, the self-sacrifice, and devotion of the farmers of America will, I believe, bring to a triumphant conclusion this great last war for the emancipation of men from the control of arbitrary government and the selfishness of class legislation and control, and then, when the end has come, we may look each other in the face and be glad that we are Americans and have had the privilege to play such a part."

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 699

Contribution from the Bureau of Soils
MILTON WHITNEY, Chief

Washington, D. C. ▼ October 16, 1918

ANALYSIS OF EXPERIMENTAL WORK WITH GROUND RAW ROCK PHOSPHATE AS A FERTILIZER.

By W. H. WAGGAMAN and C. R. WAGNER, *Scientists in Investigation of Fertilizer Resources*, assisted by R. F. GARDINER, *Scientist in Soil Laboratory Investigations.*

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INTRODUCTION.

Much doubt and difference of opinion exists concerning the fertilizer value of ground raw rock phosphate. Some agronomists and agricultural chemists have reported satisfactory results from its use both in pot and field experiments, others have decided that while the material is beneficial to a number of crops when applied under certain conditions, it is so inferior to acid phosphate that it is unwise, under normal conditions, to depend upon it as a source of phosphoric acid when one can obtain the more soluble superphosphate. Several experiment stations have concluded that ground raw rock phosphate is entirely unprofitable on most of the soils in their particular States under their present crop systems.

The use of ground raw rock phosphate directly as a fertilizer, however, has slowly increased during the last decade until now the annual consumption is in excess of 91,000 tons, involving an expenditure by the farmer of over $750,000 annually.

Most of the demand has been in the corn belt of the middle Western States, particularly in Illinois, where the State Agricultural Experiment Station has strongly recommended this material and outlined methods of treatment and application which it claims will result in the maximum benefit from its use. But ground raw rock phosphate has been used to a small extent in many other States and would undoubtedly have been more widely employed were it not for conflicting conclusions concerning its agricultural value, conclusions which in many instances have been drawn from insufficient data.

Numerous experiments have been conducted, not only in the field but in the greenhouse and laboratory as well, to test the fertilizer value of ground raw rock phosphate. While some of the field experiments have been carried on in a careful, systematic way over a term of years, others have been conducted for such a brief period and apparently with so little regard for the numerous factors influencing crop yields that it is not only unwise to draw any definite conclusions from the results but unfair to class them with those obtained from carefully conducted long-time experiments. After a careful analysis of a number of long-time fertilizer experiments, Prof. Whitney,[1] of this bureau, states that " a period of not less than 15 years of observation is required to draw any safe conclusions from fertilizer plot tests." If the results of experiments so far published, therefore, be taken without carefully weighing their relative merits, the only conclusion one could possibly reach is that ground raw rock phosphate is of very questionable value.

In giving the results of field tests with ground raw rock phosphate, the writers found it difficult to draw the line between experiments warranting discussion and those which were not sufficiently important to justify consideration in detail. Finally the plan was adopted to discuss only those field experiments which were conducted for five years or more. In some instances this plan may appear not quite fair, but almost any other treatment of the subject would result in a manuscript so bulky and so filled with data of relatively little value, that it would only serve to confuse the reader.

HISTORY.

The use in this country of ground raw rock phosphate as a fertilizer dates back to the early days of the South Carolina phosphate industry.

Holmes[2] recommended finely ground South Carolina rock for direct application to the field as early as 1870, and several of the phosphate mining concerns then operating at Charleston advertised the material for sale. Chazal[3] states that some correspondence of Prof. Charles U. Shepard shows that the latter advised the use of the Ashley phosphates in lieu of bones as far back as 1860. A number of years later (1889), when the Florida hard rock phosphate fields were discovered, a considerable tonnage of soft phosphate (consisting chiefly of aluminum phosphate), which is found associated with the hard rock, was used locally by the farmers, and in a good many instances with reported success.

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[1] Unpublished work.

[2] Phosphate Rocks of South Carolina, pp. 45–46 (1870).

[3] A Sketch of the South Carolina Phosphate Industry (1904).

Some early adverse reports on the agricultural value of raw rock phosphate, coupled with the rapid establishing of plants for the manufacture of the more soluble and undoubtedly more quickly acting superphosphate, led to the practical cessation of use of this raw material in the South, and, while spasmodic efforts have been made to revive its use, it is generally believed that the more soluble phosphates are better adapted to most of the soils and crops of the South Atlantic States.

The first recorded work with raw rock phosphate was published by the Pennsylvania Experiment Station in 1885,[1] and consisted of two experiments (one field and one box experiment) begun in 1883. The box experiment was continued for two years only, but the field experiment was conducted through a period of thirteen years.

The Louisiana station was the next to report the results of experiments with this material, publishing in 1886 [2] the yields of corn and oats obtained in several tests conducted for periods of one to two years.

Some years later this same station undertook a number of long-time experiments with raw rock phosphate, the results of which are recorded and discussed elsewhere in this bulletin.

Several other experiment stations (Florida, Connecticut, Georgia, and South Carolina) shortly afterward undertook some experiments with raw phosphates, and these have been followed by practically all the State stations east of the Mississippi River and a few of those west. The results obtained by the stations are discussed in detail further on.

THEORETICAL CONSIDERATIONS.

The fact that most deposits of amorphous phosphates are of organic origin led many to believe that this material when ground and applied directly to the soil would give results approximating those obtained from the use of nitrogenous guanos or ground bone.

A brief consideration of the manner in which deposits of rock phosphate are usually formed will show that it can not ordinarily be expected to yield its phosphoric acid as rapidly to the soil solution as the organic phosphates which have not undergone complete decomposition.

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[1] Pa. Agr. Expt. Sta., Ann. Rept. for 1884 (1885).

[2] La. Agr. Expt. Sta., Buls. Nos. 3, 4, and 6 (1886).

Some phosphate deposits, such as those found on islands of the Pacific and Indian Oceans, have resulted from the replacement of the carbonic acid in lime rock by phosphoric acid derived from overlying layers of organic material, usually the droppings of sea birds. The percentage of phosphoric acid in such excrements is quite high and is readily leached out by rain water, but the underlying coral limestone, of which such islands are often formed, takes up and fixes the phosphoric acid, forming relatively insoluble phosphate of lime.

Other phosphate deposits such as the brown-rock deposits of Tennessee are derived from phosphatic limestones by the leaching out of the more soluble carbonate of lime. The residue then consists of a porous rock containing a much higher percentage of phosphoric acid than the original material but in the form of the same relatively insoluble phosphate of lime.

While the origin of numerous deposits of phosphate is not altogether clear, in nearly every instance the nature of the rock is such that it is relatively insoluble in water and quite resistant to weathering influences. A quick response from applications of such material, therefore, is hardly to be expected unless it is either subjected to some chemical treatment by which the solubility of the phosphoric acid is considerably increased or it is mechanically ground to an impalpable powder and thoroughly distributed in the soil in such large quantities that an enormous surface of the mineral is exposed to the action of the soil waters.

In order to render the phosphoric acid soluble and facilitate its distribution in the soil, Liebig proposed to treat bones with sulphuric acid. When the nature of phosphate rock was established, Lawes applied the same treatment to that material, taking out a patent on his process in 1842. Since that date the use of acidulated phosphates has grown rapidly until now the vast bulk of the rock phosphate entering into the fertilizer industry is treated with sulphuric acid and manufactured into superphosphate.

Because ground raw rock phosphate has in many cases proved more effective on soils rich in organic matter, it is popularly supposed that certain organic acids in the soil exert a solvent influence on the rock similar to the effect produced by sulphuric acid.

The existence of such organic acids in the soil in quantities sufficient to affect appreciably the solubility of phosphate rock is very doubtful, but soils of high organic content are always rich in carbon dioxide and bacteria, both of which have an important influence on the solubility and alteration of soil minerals, and hence it is reasonable to expect an increase in the solubility of the phosphate contained therein over that of soils of low organic content. Some of the best field results with raw rock phosphate have been obtained where the material has been used in connection with stable manure or turned under with a green crop. Either of these treatments increases both the bacterial growth and the amount of carbon dioxide in the soil.

On the other hand, highly productive soils not particularly rich in organic matter and which have never been fertilized contain much of their phosphoric acid as apatite or in some relatively insoluble form. Limestone soils high in phosphate, such as those in the Bluegrass Regions of Kentucky or in the Central Basin of Tennessee, continue to yield large crops without the addition of any soluble phosphate, and frequently do not respond to such applications.[1]

Burlison,[2] in a series of pot tests in pure sand, showed that farm crops were able to utilize the phosphoric acid of rock phosphate without the aid of organic material and that the yields were greater when the applications of rock phosphate were increased.

Other things being favorable, therefore, it seems reasonable to expect a soil low in phosphoric acid to respond to the addition of ground raw rock phosphate provided that the material is very finely ground, applied liberally, and thoroughly distributed through the soil by cultivation.

METHODS OF STUDYING THE SUBJECT.

In efforts to determine the fertilizer value of raw rock phosphate three general lines of investigation have been followed, namely, laboratory work, pot or greenhouse tests, and field experiments. The last named of these methods is by far the most important and the only one of much value, taken by itself. The other lines of work, however, are useful supplements to field experiments, and their importance should not be minimized.

LABORATORY WORK.

Laboratory work on ground raw rock phosphate divides itself into the following investigations:

1. Determination of composition of rock.
2. Methods of determining availability of phosphate.
3. Effect of degree of fineness of the phosphate on its solubility or availability.
4. Effect of organic fermentation on the solubility or availability of the phosphate.

COMPOSITION OF ROCK.

While phosphate rock from various sources differs considerably in composition and grade,[3] the bulk of the phosphoric acid contained therein is combined with lime in the proportion to form tricalcium phosphate ($Ca_3(PO_4)_2$). Since this material in its natural state is rather sparingly soluble in water and very weak acid solutions, there may be little difference in the amount of phosphoric acid which the various grades of rock will yield to a definite quantity of such solvents within a limited time, provided the rock samples are ground to the same degree of fineness.

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[1] Mooers, C. A., Tenn. Agr. Expt. Sta., Bul. 86, pp. 43–44, and p. 86 (1909).

[2] Mineral Phosphates and Plant Nutrition, Jour. Agr. Research, 6, No. 13, 485–514 (1916).

[3] Bureau of Soils, Buls. Nos. 69, 76, and 81; U. S. Dept. of Agriculture Buls. Nos. 14 and 312.

There has accumulated, however, considerable data, indicating that the availability of the amorphous phosphates is greater than that of apatite, and in a recent investigation Burlison[1] found that there was apparently quite a difference in the availability of rock phosphate from different sources when measured by crops grown in pots of small size.

The presence of such an impurity as limestone may have a considerable effect on the solubility of the phosphate in certain conventional solvents, since carbonate of lime is much more readily attacked by weak or dilute acid solutions and therefore tends to reduce their solvent power either by neutralization of the acid or by furnishing a common ion (Ca). A determination of the amount of free lime present may be of considerable importance if the availability of the phosphate is to be measured by its solubility in a conventional solvent.

Phosphates of iron and aluminum, while less soluble than the phosphates of lime, are not usually present in sufficient quantities materially to reduce the solubility of the rock. Unless, therefore, there is reason to suspect that these phosphates are present in abnormal amounts their determination is hardly deemed necessary.

The most important and often the only essential determination to be made in an analysis of phosphate rock for direct application to the field is its phosphoric-acid content. Nearly all rock is sold on the basis of the phosphoric acid which it contains and the degree of fineness to which it is ground.

METHODS OF DETERMINING AVAILABILITY OF PHOSPHATES.

The solubility of natural and manufactured phosphates in water and various media has been the subject of numerous investigations. practically all of which have been carried on with a view to obtaining an index of the availability of phosphates under soil conditions.

Deherain,[2] in attempting to determine the available plant food in soils, used a dilute solution of acetic acid. Gerlach[3] and Schloesing[4] employed aqueous solutions of carbon dioxide, on the theory that the natural soil waters owe their solvent action to this gas. The results obtained by the latter investigator in determining the solubility of the calcium phosphate ($Ca_3(PO_4)_2,H_2O$) in carbonated waters and in water containing both calcium carbonate and carbon dioxide are given in Table I.

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[1] Mineral Phosphates and Plant Nutrition, Jour. Agr. Research, **6**, pp. 485–514 (1916).

[2] Ann. Agron., **17**, 445 (1891).

[3] Landw. Vers.-Stat., **46**, 201 (1896).

[4] Compt. Rend., **131**, 149 (1900).

TABLE I.—*Solubility of lime phosphate in water containing carbon dioxide and calcium carbonate.*

Solvent.	Phosphoric acid (P_2O_5) per liter.	Lime (CaO) per liter.
	Mg.	*Mg.*
Water	0.74	
1,200 cubic centimeters distilled water and 50 cubic centimeters water saturated with CO_2	6.9	
1,000 cubic centimeters distilled water and 250 cubic centimeters water saturated with CO_2	48.5	
1,250 cubic centimeters water saturated with CO_2	91.9	
Water containing 174 milligrams $CaCO_3$ and 82 milligrams CO_2 per liter	.38	100.0
Water containing 290 milligrams $CaCO_3$ and 171 milligrams CO_2 per liter	1.1	162.3
Water containing 389 milligrams $CaCO_3$ and 270 milligrams CO_2 per liter	.80	218.8
Water containing 488 milligrams $CaCO_3$ and 415 milligrams CO_2 per liter	1.77	273.3
Water containing 558 milligrams $CaCO_3$ and 541 milligrams CO_2 per liter	1.30	312.7

It will be seen that the presence of carbon dioxide in water increases greatly the solubility of tricalcium phosphate, but that the addition of calcium carbonate depresses the solubility of the phosphate. This experiment was apparently conducted with samples of relatively pure materials, and no doubt the lime phosphate was in a precipitated form. Under such conditions a greater quantity of phosphoric acid (P_2O_5) would be dissolved than from the same quantity of natural rock phosphate.

An experiment to test the solvent power of carbonated waters on various phosphatic materials was conducted by Williams[1] many years before the one just cited. The results of this experiment are given in Table II.

TABLE II.—*Solubility in water of various phosphatic materials used as fertilizers.*

Source of phosphate.	Water required to dissolve one part of the phosphate.
	Parts.
Apatite from Perth, Canada, containing 89.27 per cent $Ca_3(PO_4)_2$	222,000
Same, levigated	140,000
Finely ground bone containing 56.78 per cent $Ca_3(PO_4)_2$	5,698
Same, calcined to burn out organic matter, 92.88 per cent $Ca_3(PO_4)_2$	8,029
Adulterated commercial bone dust containing 24.32 per cent organic and volatile matters and 35 per cent $Ca_3(PO_4)_2$	4,122
South Carolina phosphate containing 57.89 per cent $Ca_3(PO_4)_2$	6,983
Same, levigated	6,544
Guano containing 49.67 per cent $Ca_3(PO_4)_2$	8,009

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[1] Chem. News, 24, 306 (1871).

It will be noted that the solubility of the amorphous phosphate (South Carolina rock) is considerably greater than the crystalline variety (apatite). Also that fine grinding increased the amount of the various materials dissolved.

Liebig,[1] Fleisher and Kissling,[2] Cameron and Hurst,[3] and Greaves[4] found that the presence of most fertilizer salts increased the solubility of phosphates of lime, and Cameron and Bell[5] showed that certain aqueous solutions increased the solubility of the various phosphates occurring in the soil.

Peterman[6] advocated an ammoniacal solution of ammonium citrate to determine the available phosphoric acid in soils. Emmerling[7] recommended a 1 per cent solution of oxalic acid to distinguish between lime phosphate and the phosphates of iron and aluminum. Hoffmeister[8] suggested an ammoniacal solution of "humic acid" for determining the various forms of phosphoric acid in soils. Fraps[9] determined the solubility of a number of soil phosphates in various strengths of hydrochloric and nitric acids as well as in 1 per cent citric acid, and tried to establish a relation between the chemically available phosphoric acid and that shown to be available by pot tests. While he found in several experiments that the order of availability as measured by N/5 nitric acid was the same as in pot tests, he also found that the difference in the feeding power of various crops and the nature of the soil influenced the degree of availability of soil phosphates. This experiment did not establish any standard for chemically available phosphoric acid in the soil. Stoddart[10] found that the digestion of 25 grams of soil with 250 cubic centimeters of N/5 nitric acid for five hours dissolved practically all of the lime phosphate but very little of the phosphates of iron and aluminum, and concluded that this test serves as an excellent indication of the amount of available phosphoric acid present in a soil. In the light of other experiments, however, the assumption that the phosphates of iron and aluminum are unavailable to crops is hardly justified.

Moore[11] attempted to find a strength of hydrochloric acid which would remove approximately the same amount of phosphoric acid from a soil as a crop of oats grown in pots. The conditions finally adopted for the extraction were to digest 200 grams of soil for five hours at a temperature of 40° C. with 1 liter of acid of such strength that it would be N/200 to methyl orange at the end of the digestion. This method, it is said, however, did not prove satisfactory where the soil had been fertilized. Hall and Plyman,[1] in an exhaustive article on the subject of "Available Plant Food in Soils," concluded, after trying numerous solvents on 19 different soils, that a 1 per cent solution of citric acid as recommended by Dyer[2] gives results more nearly showing the available plant food in soils. Dyer sought to determine the average acidity of the root sap, with a view to finding a natural solvent for plant food elements in the soil, and decided that a 1 per cent solution of citric acid most nearly approximated the average solvent power of the root sap. The theory, however, that the roots of plants excrete an acid (other than carbonic) which aids them in dissolving and securing their food has been practically abandoned. Kossowitch[3] concluded that the solvent action of plants on relatively insoluble phosphates is due to the carbon dioxide given off by the roots, but that plants are also able to supply themselves with phosphoric acid from extremely dilute solutions.

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[1] Ann. Chem. Phar. **106,** 185 (1858).

[2] Bied. Centr., **12,** 155–161 (1883).

[3] Jour. Am. Chem. Soc., **24,** 885 (1904).

[4] Jour. Biol. Chem., **7,** 287–319 (1910).

[5] Bureau of Soils, U. S. Dept. of Agr., Bul. No. 41 (1907).

[6] Recherches de Chem. et Physiol., **8,** 50 (1898).

[7] Bied. Centr., **29,** 75 (1900).

[8] Landw. Vers.-Stat., **50.** 363 (1898).

[9] Jour. Am. Chem. Soc., **28,** 823–834 (1906).

[10] Wis. Agr. Expt. Sta., Research Bul. No. 2, pp. 50–60 (1909).

[11] Jour. Am. Chem. Soc., **24,** 79 (1902).

Hartwell[4] states that it is doubtful if any solvent will extract from all soils amounts of phosphorus bearing definite relations to those removed by even a given crop. The experiments of Ellett and Hill[5] bear out this statement. These investigators first fixed the phosphoric acid of superphosphate by means of the bases occurring in soils ($CaCO_3$, $Fe(OH)_3$ and $Al(OH)_3$), and then tested the solubility of the resulting phosphates in N/5 nitric acid, neutral ammonium citrate, and 1 per cent citric acid (Dyer's method). These solutions dissolved practically all of the phosphate of lime but only from 30 to 46 per cent of the iron and aluminum phosphates. When these phosphate compounds were mixed in pots with nearly pure sand, however, and wheat, oats, and corn grown therein, the pots treated with phosphates of iron and aluminum gave greater yields than those treated with phosphate of lime, showing that the availability as determined by the growing crops was the reverse of that shown by the conventional solvents.

The results obtained by Burlison[6] in a recent investigation agree in a general way with those of Ellett and Hill, since he found that the solubility of a mineral phosphate in a 0.2 per cent solution of citric acid bore no particular relation to its availability as determined by pot tests.

Hartwell[7] suggests that a better index of the available phosphoric acid in a soil might be gained by growing turnips therein and determining the phosphoric acid present in the roots. Analyses of turnips grown on soils treated with various forms of phosphoric acid showed that the percentage of P_2O_5 in the roots was fairly consistent with the availability of the phosphates as determined by crop yields.

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[1] Jour. Chem. Soc. Trans., 81, 117–144 (1902).

[2] Jour. Chem. Soc. Trans., 65, 115 (1894).

[3] Bied. Centr. 32, 44–49 (1902).

[4] R. I. Agr. Expt. Sta., 18th Ann. Rept., p. 285 (1906).

[5] Va. Polytec. Inst., Agr. Expt. Sta., Ann. Rept. for 1909–10, pp. 44–65 (1911).

[6] Jour. Agr. Research, 6, pp. 485–513 (1916).

[7] R. I. Agr. Expt. Sta., Bul. No. 154 (1913).

In determining the trade value of fertilizer materials the Association of Official Agricultural Chemists[1] classes as available all phosphoric acid soluble in a neutral solution of ammonium citrate, and in the analyses of basic slag the association[2] has tentatively adopted Wagner's method, in which all phosphoric acid dissolved from a definite weight of the material by a certain volume of 2 per cent citric acid is considered available to crops.

Although several of these methods for determining the availability of phosphoric acid both in soils and fertilizers are useful in showing the relative solubility of various phosphates, nearly all of the processes so far suggested are empirical, and none of them are founded on a strictly scientific basis. While it has been demonstrated by actual field experiments that certain phosphates soluble in weak acids and dilute organic solutions are also active under soil conditions, in the light of both field and laboratory investigations all phosphatic materials which do not conform to these tests can not be classed as unavailable to crops. It must be remembered that the term "available" is a relative one. Practically every phosphate known is soluble to a certain extent even in pure water. The amount of phosphoric acid dissolved from the less soluble phosphates depends on the surface exposed, the quantity of solvent used, and the time of contact.

Raw rock phosphate conforms in part at least to practically all of the chemical availability tests, but its solubility in the various conventional media is materially affected by the three factors mentioned above. No method, therefore, which calls for contact for a limited time and the use of a definite quantity of relatively weak solvent, and does not state the degree of fineness to which the material should be ground, can show any sharp distinction between the amounts of phosphate available and unavailable under the conditions obtained in the soil.

EFFECT OF FINENESS OF GRINDING.

The fineness to which phosphate rock is ground undoubtedly has a very important influence on its availability to crops. Not only is it easier to distribute more uniformly the finely ground rock through the soil, but the immense amount of surface exposed by such material enables the soil water to dissolve a much greater proportion in a given time than where the rock is in relatively coarse particles.

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[1] Jour. Assoc. Official Agr. Chemists, 1, No. 4, 4–5 (1916).

[2] Idem., pp. 14–15.

As early as 1868, Voelcker[1] recognized the importance of fine grinding in facilitating the solubility of bones, but considered unacidulated coprolites and apatite practically valueless to crops. Jordon[2] found in some greenhouse work (which is discussed elsewhere in this bulletin) that pots of quartz sand treated with "floats" produced greater yields of peas, barley, and rape than those receiving the same amount of phosphate in somewhat coarser particles. Burlison[3] in a similar experiment with 60-day oats employed Tennessee brown-rock phosphate of three different degrees of fineness in a series of pots containing relatively pure sand, to which were added also the other fertilizer elements. The results of this experithese experiments are given in Table IV.

TABLE III.—*Relation of size of particles of the availability of the phosphoric acid contained therein, as measured by 60-day oats.*

Pot number.	Phosphate added.	Degree of fineness.	Grain.	Straw.
	Grams.		*Grams.*	*Grams.*
17	2.6	80 to 100 mesh	5.9	6.8
18	2.6	do	7.0	10.1
19	2.6	100 to 200 mesh	5.8	11.1
20	2.6	do	7.7	11.4
21	2.6	200 mesh and finer	8.7	11.1
22	2.6	do	7.2	13.2

Table III shows that there was considerable difference between the average yields of oats treated with the coarser and those receiving applications of the more finely ground phosphate rock.

While the value of the conventional availability tests is seriously questioned, the solvents employed serve fairly well to determine the effect of fine grinding on the solubility of a given phosphate. In the following experiments two of the most widely used phosphates produced in this country, namely, the pebble phosphate of Florida and the brown-rock phosphate of Tennessee, were employed.

Samples of these types of rock were ground to three different degrees of fineness, as follows: (1) Between 60 and 130 mesh, (2) between 130 and 180 mesh, and (3) 180 mesh and finer. The solubility of the three grades of each type was then determined according to the official method of the American Association of Official Agricultural Chemists (solubility in ammonium citrate), according to Wagner's method (solubility in 2 per cent citric acid), and according to Dyer's method (solubility in 1 per cent citric acid). In addition to these conventional determinations the solubility of the material in water saturated with carbon dioxide was determined. The results of these experiments are given in Table IV.

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[1] Jour. Royal Agr. Soc., 4, 176-196 (1868).

[2] N. Y. Agr. Expt. Sta. (Geneva), Bul. No. 358 (1913).

[3] Jour. Agr. Research, 6, pp. 507-508 (1916).

TABLE IV.—*Influence of fine grinding on the solubility of Florida and Tennessee phosphates in certain conventional solvents.*

[Analyses by R. F. Gardiner and J. A. Cullen.]

Type of rock.	Degree of fineness.	Total P_2O_5.	Percentage of total P_2O_5 soluble according to— Official method.	Wagner's method.	Dyer's method.[1]	Amount dissolved by water saturated with CO_2.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*P. P. M.*
Florida pebble	Between 60 and 130 mesh	35.53	2.76	11.54	2.55	2.0
Do	Between 130 and 180 mesh	36.27	4.66	16.10	2.59	3.0
Do	180 mesh and finer	37.03	5.54	18.66	2.57	4.0
Tennessee brown rock	Between 60 and 130 mesh	31.25	.83	8.16	2.51	2.0
Do	Between 130 and 180 mesh	29.96	2.34	8.85	2.62	4.0
Do	180 mesh and finer	26.80	3.80	17.60	3.11	4.5

[1] The solubility determinations according to Dyer's method were made on new samples.

Table IV shows that in nearly every instance the finest ground material yielded considerably more phosphoric acid to the solvents employed than the coarser material.

Several concerns now producing ground phosphate rock claim that their product is ground so that 80 per cent will pass a sieve of 200 meshes to the linear inch. While some tests run in this laboratory seem to make it doubtful if a uniform product of this degree of fineness can be placed on the market at present prices, the material should at least be ground so that 90 per cent will pass a 100-mesh sieve. Such rock will contain a large percentage of very much finer material.

EFFECT OF ORGANIC FERMENTATION.

It is generally believed by those who favor the use of raw rock phosphate as a fertilizer that the action of decaying organic matter increases the availability or effectiveness of the phosphate in the soil. While actual field experiments lend support to this conclusion, efforts to prove this point in the laboratory have not been altogether satisfactory.

Lupton[1] mixed floats with cottonseed meal and allowed the mixture to ferment. Citrate-soluble phosphoric acid was determined at the beginning and from time to time during the three months of the experiment. The results were inconclusive. McDowell[2] allowed a mixture of floats and manure to ferment in a barrel for 13 months and compared the water-soluble and citrate-soluble phosphoric acid present at the beginning and at the end of that period. No increase in the amount of citrate-soluble phosphoric acid was noted. In a similar experiment Holdefleiss[3] found but little increase in the citrate solubility of phosphate rock which had been mixed with various organic materials and inorganic salts and allowed to ferment for eight months. Pfeiffer and Thurmann[1] found that the composting of decaying organic matter and phosphates produced but a slight increase in the citrate solubility of phosphate rock and actually decreased the solubility of acid phosphate.

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[1] Ala. Agr. Expt. Sta., Bul. No. 48, pp. 1–10 (1893).

[2] Pa. Agr. Expt. Sta., Ann. Rept. 1907–8, p. 175.

[3] Heiden, Dungerlehre, 2, 509.

Truog,[2] however, states that these experiments are open to criticism, since no blanks or checks (P_2O_5 determinations) were run on the organic materials mixed or composted with the phosphates. This author carried on a number of laboratory experiments to study the effect of decomposing organic matter on the solubility of finely ground rock phosphate. This solubility, however, was determined in nearly every instance in a 0.2 per cent solution of citric acid, which can not be considered a proof of, nor necessarily an index to, the availability of the phosphatic material.

In his first experiment Truog made up the following mixtures in 1-gallon glazed jars, each provided with a hole in the bottom:

No. 1: 2.7 kilograms sand, 25 grams floats.
No. 2: 2.7 kilograms sand, 25 grams floats, 300 grams grass.
No. 3: 2.7 kilograms sand, 300 grams grass.
No. 4: 2.7 kilograms sand, 26 grams floats, 300 grams manure.
No. 5: 2.7 kilograms sand, 300 grams manure.

The sand used in this experiment analyzed 97.9 per cent silica; the floats consisted of a high-grade finely ground rock phosphate containing 34 per cent phosphoric acid (P_2O_5). The grass was fresh fine grass finely chopped, and the manure was fresh cow dung without any litter.

The contents of each jar were thoroughly mixed and an optimum amount of water was maintained in the jars for a little over four months. Both the water-soluble and citric-soluble phosphoric acid present in the mixtures were then determined. The results of these analyses are given in Table V.

TABLE V.—*Parts of phosphoric acid (P_2O_5) per million parts of the extracting solution.*

Jar No.	Treatment.	P_2O_5 extracted from jars by 3 liters of distilled water.	P_2O_5 extracted from 150 grams of material by 300 cubic centimeters of 0.2 per cent citric acid in 24 hours.	P_2O_5 extracted from 150 grams of material by 300 cubic centimeters of 0.2 per cent citric acid in 8 days.	P_2O_5 extracted from 60 grams of material by 1 per cant NaOH
		P.p.m.	*P.p.m.*	*P.p.m.*	*P.p.m.*
1	Quartz and floats	1.5	116.0	149.0	7.5
2	Quartz, floats, and grass	88.0	68.5	99.0	11.0
3	Quartz and grass	88.0	26.0	32.0	8.7
4	Quartz, floats, and manure	71.0	88.0	118.0	12.5
5	Quartz and manure	67.0	66.5	57.0	9.3

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[1] Landw. Vers-Stat., 343 (1896).

[2] Wis. Agr. Expt. Sta., Research Bul. No. 20 (1912).

The fermentation of organic matter apparently had little or no effect on the solubility of finely ground rock phosphate in water and a depressing effect on its solubility in 0.2 per cent citric acid solution. In regard to the rock's solubility in 1 per cent sodium hydroxide solution, however, this depression is not so marked if indeed there is any. This investigation included a number of other interesting experiments, showing the solvent effect of carbon dioxide on natural phosphates and the great increase in the quantity of this gas in soils treated with manure. The pot work with raw rock phosphate conducted by Truog is discussed elsewhere in this bulletin.

In summing up the results of his work Truog concludes that the "solubility of phosphate as measured by a solvent like 0.2 per cent citric acid may be very different from the availability as measured by a growing crop." He thinks that the rôle which organic matter plays in rendering raw phosphates more available in the field is due to the increased quantity of carbon dioxide resulting from organic decomposition and the better distribution of the phosphate which is brought about by mixing it intimately with the organic material.

Sackett, Patten, and Brown[1] in an investigation on the solvent action of soil bacteria upon the insoluble phosphoric acid of bone and raw rock phosphate found that certain types of soil bacteria have the power of converting small quantities of insoluble phosphates into soluble form independent of acid formation, but that when bacterial growth is accompanied by the formation of acid the amount of phosphate dissolved is considerably greater.

Tottingham[2] found, however, that in mixtures of rock phosphate and manure both the water-soluble and citrate-soluble phosphoric acid were reduced by fermentation.

In a later and more exhaustive investigation Tottingham and Hoffman[3] showed that the action of fermenting manure on natural phosphates is much more complex than was formerly supposed. These investigators claimed that the decreased solubility of the phosphates in such mixtures was due to the fixing or absorption of the phosphorus by the manure organisms, but that the availability of the phosphorus in the cells of such organisms as measured by a growing crop (pot test) was as great as that in acid phosphate. Moreover, after fermentation has practically ceased the absorbed or altered phosphate is released in forms soluble in carbonated waters. The final conclusions reached in this investigation were that advantageous results are obtained by composting rock phosphate with fermenting manure, but that it is inadvisable to practice the same scheme with acid phosphate.

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[1] Mich. Agr. Expt. Sta., Bul. No. 43 (special), (1908).

[2] Science (n. s.) 35, 390 (1912).

[3] Wis. Agr. Expt. Sta. Research Bul. No. 29, pp. 273–321 (1913).

Forbes and Fritz[1] suggested the introduction of floats into the silo in order that the fermentation process and the subsequent passing of the ensilage through the animal's body would aid in rendering the rock phosphate more soluble. The following table gives a summary of the analytical results obtained by these investigators.

TABLE VI.—*Phosphorus in silage corn with and without added floats, and in silage made therefrom.*

Material.	Average content of phosphorus on water-free basis.				
	Total.	Water soluble.	Citrate soluble.	Soluble in 0.2 per cent HCl.	Water soluble plus citrate soluble.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Untreated green silage corn	0.207	0.149	0.021	0.083	0.170
Silage from untreated corn	.224	.160	.008	.111	.168
Green silage corn plus floats	.371	.136	.061	.172	.197
Silage from treated corn	.384	.157	.060	.237	.217

If the total quantity of phosphoric acid in the material is considered, it will be seen that the fermentation process actually decreased the percentage of water-soluble plus citrate-soluble phosphoric acid present in the silage corn. Fermentation also produced little or no effect on the citrate solubility of floats mixed and charged to the silo with the corn. The amount of phosphate dissolved by a 0.2 per cent solution of hydrochloric acid, however, was considerably increased by the ensilage process. If this were an index of availability (an assumption which is hardly warranted) the mixing of phosphate rock with ensilage might be considered good practice.

Mooers,[2] however, carried this investigation somewhat further and actually determined the citric-soluble phosphate in the dung of animals fed with ensilage treated with floats, comparing the results with the dung of similar animals fed with untreated ensilage.

The treated ensilage was produced by charging the silo with finely ground rock phosphate and corn at the rate of 2 pounds of the former to 100 pounds of the corn. It was assumed that the increased amount of total phosphoric acid in the dung of the animals fed with the treated ensilage was due to the rock phosphate in the ensilage. In order to have a check on the effect of fermentation and the subsequent digestive process on the solubility of the phosphate, an amount of rock phosphate equal to that in the dung produced from the treated ensilage was added to the dung produced from untreated ensilage. The results of this investigation are summarized in Table VII.

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[1] Jour. Ind. and Eng. Chem., 6, 222 (1914).

[2] Jour. Ind. and Eng. Chem., 6, 487–8 (1914).

TABLE VII.—*Phosphoric acid (P_2O_5) voided in dung of animals fed with phosphated and unphosphated ensilage.*

Material.	Phosphoric acid found.	
	Total.	Soluble in 0.1 per cent citric acid.
	Per cent.	*Per cent.*
Dung from cow No. 10 (untreated ensilage)	1.17	0.76
Dung from cow No. 10 (untreated ensilage) plus a quantity of floats equal to that in the dung from cow No. 30 fed with treated ensilage	5.95	.88
Dung from cow No. 30 (phosphated ensilage)	5.95	1.05
Dung from fawn heifer (untreated ensilage)	1.78	1.38
Dung from fawn heifer (untreated ensilage) plus a quantity of floats equal to that in the dung from the blue heifer fed with phosphated ensilage	9.34	1.47
Dung from blue heifer (phosphated ensilage)	9.34	1.86

Apparently the combined processes of fermentation and subsequent digestion of the phosphated ensilage produced small increases in the citric solubility of the rock phosphate, but in view of the fact that the animals would eat but limited quantities of the treated ensilage, and that it was doubtful whether the increase in solubility was due to the ensilage process or to animal digestion, he concluded that this method did not offer a practical means of rendering the phosphoric acid of raw rock phosphate available for agricultural purposes.

In a laboratory investigation on the effect of phosphates and sulphates on soil bacteria Fred and Hart[1] found that the addition of such materials to a soil in soluble form increased the ammonification, carbon dioxide evolution, and total number of bacteria. While these effects were much less marked in the case of a relatively insoluble phosphate (bone ash), the suggestion that the increase in yield resulting from phosphate applications is due in part to the promotion of bacterial activity, which in turn increases ammonification (or the supply of available nitrogen) and also the carbon dioxide content of the soil, seems reasonable. The latter compound is effective in bringing about the solution of a further quantity of phosphate mineral.

Hopkins and Whiting,[2] in an article entitled "Soil Bacteria and Phosphates," showed that nitrous acid produced by the action of nitrate bacteria upon ammonium salts dissolved phosphate of lime, the amounts of lime and phosphoric acid in solution increasing as the quantity of oxidized nitrogen increased. These same authors also point out that if all the nitrogen required by standard crops were obtained from the oxidation of ammonia or ammonium salts and the acid thus produced made to act upon rock phosphate the amounts of phosphoric acid and lime thus rendered water soluble would be many times greater than required by these same crops.

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[1] Wis. Agr. Expt. Sta. Research Bul. No. 35, pp. 35–66 (1915).

[2] Ill. Agr. Expt. Sta., Bul 190, pp. 395–406 (1916).

Nearly all the experiments so far considered for determining the effect of decaying organic matter upon rock phosphate have depended on some weak solution (usually an acid) to measure the availability of the phosphate thus treated. Truog's conclusion that the conventional laboratory methods for measuring the availability of phosphates are unsuitable under certain conditions seems quite logical. Take, for instance, the fermentation of manure, which results in the formation of alkaline products, which predominate for a time at least over the acid products. There seems little reason to suppose that changes in raw rock phosphate brought about by such fermentation can be measured by the solubility of the phosphate in acid solution.

It is true that after the fermentation has proceeded further and the alkaline products have been largely evolved or neutralized, or after fermentation has ceased and the altered phosphate has been released by the death of the organisms which absorbed it into their cells, one might expect that the solubility of the phosphate in water saturated with carbon dioxide would be an index to its availability. But while carbon dioxide increases quite appreciably the solubility of the difficultly soluble phosphates, this effect is limited at any one time by the amount of the gas which can enter into solution. During the growing season, however, the constant absorption of the dissolved phosphate by plant roots allows the carbon dioxide to act continually upon more phosphatic material. Decaying organic matter in contact with raw phosphate, therefore, should be furnishing carbon dioxide sufficient to keep a fairly constant supply of phosphoric acid in the soil solution, and therefore the availability of the phosphate should be considerably increased by its presence.

POT AND GREENHOUSE WORK.

The main advantage of pot work in testing out fertilizer materials lies in the fact that the conditions under which the experiments are conducted can be to a large extent controlled.

Soil in the same mechanical condition and of the same chemical composition can be obtained for a series of pots with little difficulty. Uniform conditions of moisture and temperature can be maintained throughout the growing period, and such disturbing factors as blight, insect pests, and injuries from heavy rain, hail, or high winds can be reduced to a minimum.

On the other hand, the slightest variation in the conditions of the experiment may produce such differences in the crops as to lead to very erroneous conclusions. Careful selection of seed, uniform packing of the soil to insure equality in drainage, and a thorough distribution of the fertilizer material are essential in order to obtain reliable data from pot tests.

Another disadvantage in pot work lies in the fact that it is difficult to grow many plants to maturity in pots because of the limited space in which the root systems have to expand and forage.

While pot tests with fertilizer materials are valuable for preliminary experiments and are also useful supplements to field work, the results obtained therefrom can not be regarded as final proof of the value of the fertilizer material under investigation. In fact, pot tests do not necessarily serve as an index to the results which will be obtained in the field.

The amount of pot or greenhouse work on ground raw rock phosphate is comparatively small. What has been done is discussed further on in the detailed descriptions of the work of the State experiment stations.

FIELD EXPERIMENTS.

The final proof of the value of a fertilizer material must rest upon field experiments, but field experiments, unless carefully conducted with due regard to the numerous factors influencing crop yields, are often worse than valueless.

Because of limited knowledge of these factors, the earlier agronomists had a tendency to publish the results of field work conducted for a year or two only and to draw conclusions from very meager data. Unfortunately, even now the results of field experiments are often published without at the same time reporting data or mentioning certain factors which would be a great aid in interpreting the significance of the crop yields. Moreover, the experiments (particularly raw rock phosphate tests) are conducted in such different ways and under such a variety of conditions that it is impossible to reduce them to a uniform basis for the sake of comparison. The desirability of having field investigators employ the same methods and a minimum standard in both variety and fertilizer experiments has been pointed out by Piper and Stevenson.[1]

In considering the results of field experiments with raw rock phosphate, careful attention should be given to the following factors:

1. Uniformity of experiment field.
2. Topography and drainage conditions.
3. Physical and chemical composition of the soil.
4. Previous treatment of field.
5. Climatic conditions.
6. Injuries from disease, insects, and animals.

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[1] Standardization of Field Experimental Methods in Agronomy. Proc. Am. Soc. Agron., 2, 70–76 (1910).

7. Kind of crops grown and selection of seed.
8. Rate of application and uniform distribution of phosphates.
9. Methods of comparing raw rock with other phosphates.
10. Effect of other fertilizers.
11. Number and distribution of plots.
12. Duration of experiment.

UNIFORMITY OF EXPERIMENTAL FIELD.

The greatest care should be exercised in selecting a field containing soil of a uniform character throughout, for unless the soil on the various plots has the same productive power or the probable difference in its natural fertility on these plots is determined, the yields obtained from the application of fertilizers may have little or no meaning. A soil survey of a field is of great importance, but such a survey unless supplemented by borings may not give sufficient information, since an apparently uniform soil may so vary in depth from place to place as to cause wide differences in the productivity of the various plots. Hall and Russell[1] state that a simple yet sensitive method of determining the uniformity of a soil consists in ascertaining the percentage of moisture in samples collected from various parts of a field at the same time to the same depth. An even more sensitive test, it is said, consists in determining the percentage of nitrates in such samples.

Piper and Stevenson[2] state that it is difficult to say what is the ordinary error due to soil inequality. Hall and Russell[3] state that the Rothamsted records show that there is an error of 10 per cent on plots where the past treatment has been uniform and general conditions were favorable for experimental work.

In conducting fertilizer experiments in the field attempts have been made to determine the so-called "natural fertility" of the plots subsequently treated with fertilizers. Offhand the most logical method appears to be to complete at least one rotation of the system to be employed during the experiment without the addition of any fertilizer whatever. The usefulness of this method of valuing the plots, however, appears very doubtful. In fact, it might well be asked, "Is there such a thing as natural fertility under field conditions when these conditions vary so greatly from year to year?" Lyon[4] has shown that when corn, oats, and wheat were grown for several years on the same fields no definite relation was shown between the yields of the various plots from year to year.

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[1] Chem. News, 102, 180 (1910).

[2] Standardization of Field Experimental Methods. Proc. Am. Soc. Agron., 2, 70–76 (1910).

[3] Error of Experiment in Agricultural Field Tests. Chem. News, 102, 80 (1910).

[4] Experiments to Estimate Errors in Field Plat Tests. Jour. Am. Soc. Agron., 3, 89–114 (1911).

Where the check plots and those receiving various fertilizer treatments are replicated several times throughout the experiment field, absolute uniformity in a field is not so essential. This point, however, is discussed under the heading "Number and Distribution of Plots."

TOPOGRAPHY AND DRAINAGE CONDITIONS.

The soil of an experiment field may be fairly uniform throughout, but unless the topography and drainage conditions are regular, certain parts of the field will be more productive than others. Drainage, whether natural or artificial, is seldom uniform on a field.[1] If a soil has good underdrainage, but the topography of the field is not regular, the accumulation of silt and the greater moisture content of the low ground will probably render these depressions more productive than the high ground. On the other hand, if the low ground is poorly drained, excessive moisture in the spring may keep the ground cold, delaying greatly the growth of the crop, preventing aeration of the soil, and hindering the development of root systems sufficiently extensive to keep the crop from suffering from droughts encountered later in the year.

Topographic irregularities may also affect crop yields by causing certain parts of a field to be shaded more than others. The shaded areas may or may not produce greater yields than the unshaded, depending on the climatic conditions and the crops grown.

Since it is frequently not practicable to obtain an experiment field free from topographic irregularities, the plots should be laid off or distributed in such a way that these irregularities are apportioned (as nearly as possible) equally among the various treatments.

PHYSICAL AND CHEMICAL COMPOSITION OF SOILS.

Fertilizers affect various soil types and soils varying in chemical composition quite differently. Very sandy soils, low in organic matter, ordinarily respond quickly to the soluble fertilizers, but owing to their low absorptive capacity they may often be leached of their soluble salts during excessive rains. Clay soils, on the other hand, if kept in good tilth, have a great absorptive capacity, but often do not respond so readily to fertilizer treatment until they have been heavily limed. Soils rich in organic matter usually respond more quickly to the relatively insoluble fertilizers than those of low organic content, but here again the soil type and its mineral constitutents are factors which must be considered.

The digestion of a soil with hydrochloric or nitric acid of various strengths is of little value as an index to its fertility or to its content of available plant food, but the determination of the total quantities of the fertilizer elements (by fusion with sodium carbonate) is frequently of considerable importance, particularly if supplemented by a mineralogical examination.

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[1] Hall, A. D., and Russell, E. J. Chem. News, 102, 180 (1910).

Some soils high in phosphoric acid seem little affected by applications of phosphatic fertilizers, while in other soils the lack of phosphoric acid appears to be the factor limiting their fertility.

PREVIOUS TREATMENT OF FIELD.

If a soil is to be tested to determine its responsiveness to a phosphatic fertilizer, it is obvious that it should not have been treated with phosphates a short time before the experiment. Again, unless the experiment is undertaken primarily to show how a badly managed soil may be restored to former fertility, care should be taken that the soil is not in a "run-down" condition, due to improper handling and cropping. Ordinarily a field should be selected on which the soil is in a condition as nearly as possible like its original state.

Since most of our cleared land has been cultivated and much of it fertilized, it is not often possible to obtain a field which is immediately available for experimental purposes. It is often well, therefore, to allow a field to lie fallow for a year or so before using it for plot work in order that the effect of previous treatments may be reduced to a minimum. In any event the history of the field for a few years prior to the experiment should be recorded.

CLIMATIC CONDITIONS.

The temperature, rainfall, sunshine, wind, and to a large extent, blight, and insect pests are factors beyond control in field work.

Because of the early stimulation produced by a soluble fertilizer a late frost may cause more damage to plots thus treated than to those on which a less soluble fertilizer has been used. On the other hand, early stimulation and the quick maturity of certain crops are almost essential in some of our Northern States in order that they may be harvested before the early frost.

High winds or hailstorms may also cause more damage to the better-developed crop than to that which is backward for lack of fertilizer. If such a factor is not considered the final results may lead to very erroneous conclusions. Excessive rains will sometimes leach a soluble fertilizer out of a sandy soil so quickly that its full effect will not be felt and the less soluble fertilizers will appear to greater advantage. On the other hand, the early stimulation produced on a plot by a soluble fertilizer may later enable the plants to resist a severe drought more effectully than those on a plot which has been treated with a less soluble fertilizer.

INJURIES FROM DISEASE, INSECTS, AND ANIMALS.

Injuries from disease, insects, and animals are sometimes so great as completely to destroy the value of a year's work. The relative damage to certain plots frequently may be estimated and allowances made, but where the injury is considerable, it is often wise to throw out the results entirely. Hall and Russell[1] state that "the unequal incidence of disease is sometimes very troublesome." It is certainly rare if the various plots of an experiment field are equally affected by one or more of the above injuries; so, no matter how slight the damage may appear, it should be recorded and mention made of it in publishing the field results.

KIND OF CROP GROWN AND SELECTION OF SEED.

Experience has shown that for trucking purposes, where the delay of a week or less in the maturing of a crop will often mean the difference between profit and loss to a farmer, the water soluble fertilizers are much more desirable than the relatively insoluble varieties. Some crops also seem better able to utilize the less soluble phosphates than do other crops.[2] Extensive root systems may enable certain plants to forage for their food better than those which feed over a more limited area.

The selection of uniform seed is also an important factor, particularly when dealing with small plots. In order to decrease the probable variation in individual productiveness of corn grains, Lyon[3] suggested the plan of planting all the plots in an experiment with kernels from the same ears. While such a scheme is not possible in the case of many other crops, the selection of seed either by mechanical or other means can not be sufficiently emphasized.

UNIFORM DISTRIBUTION OF THE FERTILIZER.

In order to obtain the maximum benefit from an application of fertilizer a thorough distribution in the soil is necessary. The root systems of some plants are so extensive that they feed over a very wide range, and unless the fertilizer has affected the soil in the vicinity of all the root hairs, full benefit from the application can not be obtained. In the case of a soluble fertilizer it is not necessary to exercise such extreme care in application, since the distribution is largely brought about by rain and the circulation of the soil water, but with relatively insoluble fertilizers, such as basic slag, bone meal, and ground rock phosphates, the distribution must be brought about by mechanical means.

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[1] Error of Experiment in Agricultural Field Tests. Chem. News. 102, 180 1910).

[2] Me. Agr. Expt. Sta. Ann. Rept. for 1898 (1899). R. I. Expt. Sta., Bul., 163, p. 516–560 (1915).

[3] A Test of Planting Plots With the Same Ears of Corn to Secure Greater Uniformity in Yield. Proc. Am. Soc. Agron., 2, 35–37 (1910).

A brief consideration of the facts will show how important it is that applications of raw rock phosphate should be heavy in order that the material may have a fair trial.

An average soil contains 0.113 per cent of phosphoric acid (P_2O_5) or 1.98 tons per acre-foot. If such a soil has been given thorough cultivation for a number of years the phosphoric acid contained therein should be fairly well distributed, at least much better than it is possible to distribute a relatively small application of raw rock phosphate in a limited time by mechanical means. It hardly seems possible that such a soil could respond to applications of rock phosphate supplying an amount of phosphoric acid equivalent to only 1 or 2 per cent of that which it already contains in a form nearly if not quite as available. An application of 1,300 pounds per acre of average raw rock phosphate (30 per cent P_2O_5) would increase the quantity of phosphoric acid already present in an average soil approximately 10 per cent.

Hopkins[1] in his recommendations for soil treatment advises the use of raw rock phosphate on soils containing phosphoric acid in subnormal amounts at the rate of 1,000 pounds per acre every five or six years (preferably in connection with farm manure).

Truog[2] of the Wisconsin Experiment Station conducted a pot experiment in which he showed that where raw rock phosphate was very thoroughly mixed with ground quartz much better yields of corn and oats were obtained than where only ordinary care in mixing was practiced.

The use of applications of from 1,000 to 2,000 pounds of very finely ground raw rock phosphate every few years and the mixing of the same intimately with the soil by thorough cultivation should bring about the desired distribution. In this way a large surface of the relatively insoluble material is exposed to the action of the soil water, and much more of the phosphate can therefore be dissolved within a limited time.

METHODS OF COMPARING VARIOUS PHOSPHATES.

In nearly all of the field experiments so far conducted to compare the relative fertilizer values of ground raw rock phosphate and the more soluble phosphates, three general methods of application have been followed: (1) Equal weights of the various phosphatic materials have been applied, usually at a medium rate per acre. (2) The various phosphates have been added in such quantities as to furnish equal amounts of phosphoric acid to the soil, the applications usually being at a rate supplying phosphoric acid sufficient for one year's crop. (3) The several phosphates have been applied in quantities representing equal money values at the particular time and in the particular locality in which the experiment was conducted.

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[1] Ill. Agr. Expt. Sta.. Bul. No. 123 (1908).

[2] Wis. Agr. Expt. Sta., Research Bul. No. 20, p. 42–45 (1912).

Unfortunately, the first method of comparison has been the one employed in many field experiments, and while the results obtained are of some value, the method is very illogical, both from a scientific and economic viewpoint, since there are wide differences in the phosphoric acid-content of the various phosphates and the cost of these phosphates differs greatly. The only points in favor of such a method of comparison are that the amount of labor expended in spreading equal quantities of phosphatic material is the same and that all experiments conducted according to this method are to a certain extent comparable.

If the rôle which the more soluble phosphates play in the soil was simply that of supplying plant food, and the cost of phosphoric acid in its various forms was practically the same, the second method of comparison would be the logical one to follow. Moreover, all experiments conducted according to this method are also to a certain extent comparable. But water-soluble phosphates perform other functions in the soil which are often as important as the direct supplying of plant food to the growing crop. Not only do they affect the solubility of the soil minerals, but they influence and stimulate bacterial life and alter the physical condition of the soil. Because of the ease with which they are distributed in the soil and the quantity of soluble sulphates with which they are usually associated (in acid phosphate), they can not but be more energetic in their action than equal amounts of phosphoric acid in the form of relatively insoluble phosphates, and therefore a comparison of the two classes of phosphates based on equal applications of phosphoric acid is almost certain to be favorable to the soluble variety, even though the cost of the less soluble phosphates is usually considerably less.

The third method of comparing the various classes of phosphates has much to recommend it, since the effectiveness of the insoluble phosphates must depend largely on their thorough distribution in the soil, a distribution which can only be brought about by heavy applications of very finely ground material. Moreover, the relative value of two fertilizer materials must in the end be determined by the financial returns obtained from equal investments in the two forms. In many localities the price per ton of finely ground raw rock phosphate is about one-half that of acid phosphate or basic slag and one-third that of bone meal. Since the average rock phosphate contains about twice as much phosphoric acid as acid phosphate, the same amount of money will frequently purchase four times as much insoluble as soluble phosphoric acid.

Many experiments conducted according to this third plan, however, are not comparable since not only do the prices of the two forms of phosphoric acid vary considerably in different localities, depending on the distance to the mines and fertilizer factories, but the margin of difference also fluctuates from year to year, depending on market and labor conditions.

While this third method of comparison appears much fairer than the first and second, it is open to objections from a strictly business standpoint.

Practically all of the more ardent supporters of ground raw rock phosphate as a fertilizer concede that full benefit can not be gained from applications of such material until it has been allowed to remain in the soil for a year or more, and that it becomes increasingly effective as it becomes more thoroughly distributed through cultivation and is exposed to the action of certain soil solvents. This means the investment of capital which does not pay its full interest for some years, while an equal amount of money invested in acid phosphate may pay good interest the first year. The following plan, which does not yet seem to have been tried, appears to be a more logical method of comparing the two classes of phosphates:

Apply the first year the several phosphates in quantities representing equal money values. When the crops are harvested, any increase from the acid phosphate plots over and above that from the raw rock plots reinvest in acid phosphate to be applied to the next crop of the acid phosphate plot, thus keeping the net profit from the two plots constantly equal for a number of years until sufficient time has elapsed for the raw rock to have reached its maximum effectiveness.

Hopkins has proposed and followed a scheme somewhat similar to the above in the addition of manure or crop residues to variously treated plots. His plan consists in adding to each treated plot after the first year these materials in quantities equivalent to the amounts which would be produced from the crop grown on that particular plot.

In considering the field work of the experiment stations, discussion of the profits obtained from various fertilizer treatments have in most instances been omitted since the cost of fertilizer materials as well as most crops vary from year to year and place to place. It was thought best, therefore, to allow those sufficiently interested in the subject to figure the financial returns for any particular time and locality.

EFFECT OF OTHER FERTILIZERS.

It is maintained by many agricultural investigators that it is not possible to ascertain the phosphoric acid requirement of a soil and crop until nitrogen and potash have been supplied in optimum quantities. In other words, since these three fertilizer elements are taken up in a definite ratio by various crops, an adequate supply of any two elements must be present in the soil solution before the plants can utilize their full quota of the third. While this is to a certain extent true, the methods employed in bringing about this end by no means show conclusively that only the optimum quantities of the fertilizer elements are present. For instance, the application of potash to a soil until a crop no longer responds to further additions of this element simply means that there is a limit above which potash when applied alone gives no increase in yield. But potash may be present in the soil solution in far greater quantities than can be utilized by the plant. The excess over and above that required to grow a maximum crop may be performing any or all of several functions just as important as the direct supplying of plant food. Moreover, the addition of a phosphatic or nitrogenous fertilizer may entirely alter the function of the excess potash and will certainly affect the nutrient qualities of the soil solution and the feeding powers of the crop.

It has been pointed out by Cameron[1] that fertilizers not only affect the chemical composition of the soil by the actual addition of salts or organic compounds, but they alter the nature and solubility of the minerals already present. They also have an important influence on the physical condition of the soil, its bacterial content,[2] and upon other active biological agents which directly or indirectly affect plant growth.

One of the most conclusive proofs that the plant food theory is inadequate to explain entirely the action of fertilizers is the fact that stable manure, which is recognized generally as the most effective of all fertilizers, contains the three elements, nitrogen, phosphorus, and potassium, in quantities entirely insufficient to account for the increase in yields obtained from ordinary applications of this substance.

No matter which view is taken concerning the action of fertilizers, the conclusions are in a general way the same, i. e., the application of one fertilizer has an important influence on the action of another. In the case of raw rock phosphate it has been pointed out that most fertilizer salts exert a solvent effect upon this material, and therefore it is reasonable to expect its effectiveness to be somewhat increased where it is applied in conjunction with commercial forms of nitrogen and potash.

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[1] The Soil Solution, pp. 105–109 (1911).

[2] Fred and Hart. Research Bul. No. 35, pp. 35–66, Wis. Expt. Station (1915).

NUMBER AND DISTRIBUTION OF PLOTS.

It has been pointed out by various investigators that a very much clearer and more accurate knowledge of the value of fertilizer treatments can be gained by employing on a limited area many small plots, repeating each fertilizer treatment as well as the checks on several well distributed plots, than on the same area where larger plots but fewer duplicates are employed.

Piper and Stevenson[1] state that a long period of experimentation as well as the replication of plots tends to reduce probable error. Mercer and Hall[2] in summing up the results of an investigation on "Errors of Field Experiments," state that in field trials the error diminishes with increasing size of the plot, but the reduction in error is small when the plot is above one-fortieth acre. These authors recommend that in any field experiment each unit of comparison (variety, method of fertilizing, etc., according to the object of the experiment) should be given five plots of one-fortieth acre each, systematically distributed within the experimental area. Lyon[3] concludes that an area of one twenty-fifth acre of land, in four widely separated plots, devoted to any one test, secures a much greater degree of accuracy than the same area of land in one body. Olmstead[4] states that the replication of plots is a great satisfaction both to the experimenter and the readers of the literature, since it enables both to determine whether the results show any valid conclusions by giving them a means to estimate the precision of the work.

Whitney[5] states, "It is obvious that if the range of the yields of the different fertilizer plots among themselves is no greater than the range of the yields of the check plots among themselves, the relative effect of the different fertilizers would have no practical significance. Very rarely are there duplicates of any fertilizer treatment, and this is a weakness of the system. There are admittedly wide variations in the yield of check plots, and to determine the real yield under fertilization, it is just as important to have eight or ten duplicate fertilizer plots as it is to have that number of duplicate check plots."

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[1] Standardization of Field Experimental Methods in Agronomy. Proc. Am. Soc. Agron., 2, 72 (1910).

[2] Experimental Error of Field Trials. Jour. Agr. Sci., 4, pt. 2, 107–127 (1911).

[3] Experiments to Estimate Errors. Proc. Am. Soc. Agron., 3, 114 (1911).

[4] Some Applications of the Method of Least Squares to Agricultural Experiments. Jour. Am. Soc. Agron., 6, 202 (1914).

[5] Unpublished work.

DURATION OF EXPERIMENTS.

Because of the numerous conditions just discussed, some of which are beyond control and some of which vary in spite of the exercise of the greatest care, it is obviously unwise to draw conclusions from field experiments which have been conducted for a short time only. Climatic conditions vary so greatly from year to year that in order to gain an accurate knowledge of the value of a fertilizer material the same crop should be grown several times on the same land. Where proper systems of rotation are practiced it takes from 6 to 20 years to accomplish this end. In studying the effect of the less soluble fertilizers, time plays a very important part. Not only does the material often become more soluble, but it becomes more thoroughly distributed in the soil from year to year, and hence is more readily available to the root systems of crops.

RESULTS OF EXPERIMENTS.

ALABAMA.

No field experiments with raw rock phosphate continuing beyond three years have been conducted by the Alabama station. Two series of cooperative one-year experiments, however, were carried on, one in 1891,[1] consisting of 25, and the other in 1892,[2] consisting of 35 experiments. In these experiments equal amounts of acid phosphate and raw rock phosphate were compared but they were applied at a rate (240 to 300 pounds per acre) considerably below that at which the latter should prove effective. In these experiments the average yields of the acid phosphate plots were appreciably greater than those of the raw rock plots, though the latter showed considerable gains over the average of the checks.

A field experiment conducted for three years was reported by the Alabama station in 1913.[3] The general scheme and results of this experiment were in accord with those just mentioned, but the yield of the raw rock plot the third year was almost identical with that of the acid phosphate plot.

CONNECTICUT.

The work of the Connecticut station with raw ground rock phosphate has been very limited, none of the experiments having been conducted sufficiently long to warrant repetition in detail. An experiment began in 1887[4] and continued for three years[5] on the same field was conducted for the purpose of comparing the effects of various phosphates on Indian corn.

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[1] Ala. Agr. Expt. Sta., Bul. No. 23 (1891).

[2] Ala. Agr. Expt. Sta., Bul. No. 34 (1892).

[3] Ala. Agr. Expt. Sta., Bul. No. 173, p. 139 (1913).

[4] Conn. Agr. Expt. Sta., Ann. Rept. for 1888, pp. 110–117 (1889).

[5] Conn. Agr. Expt. Sta., Ann. Rept. for 1889 (1890).

The plots were treated with liberal applications of potash and nitrogen in readily available form and the various phosphates were applied in quantities representing (at that time) equal money values. During the second and third years of the experiment no further additions of phosphates were made, in order that their residual effects might be studied, but the applications of potash and nitrogen carriers were made each year. During the first year of the experiment the plot treated with acid phosphate showed to considerably greater advantage than those receiving raw ground South Carolina rock (560 pounds per acre), but in the second and third years (with no further additions of phosphates) the production of the acid-phosphate plot fell off, while that of the raw-rock plot increased to such an extent that it surpassed the yield obtained from the acid-phosphate plot during the first year of its application.

The results of 17 other short-time experiments, 15 of which were continued for only one year, were reported by the Connecticut station[1] between the years 1888 and 1895, but while most of these showed indications of beneficial results from the use of raw rock phosphate, the data given are too meager to warrant serious consideration.

While the results of the field work with raw rock phosphate so far presented by the Connecticut Experiment Station must be regarded as only indications at best, they are nevertheless favorable to the use of raw rock phosphate.

DELAWARE.

The only experiment with natural phosphates yet reported by the Delaware station was a pot test conducted by W. H. Bishop[2] in 1893 in which a study was made of the effects of various phosphates (in combination with potash and nitrogen carriers) on the yields of soy beans planted in three different types of soil.

Although the soluble phosphates led all the others, the short duration of this experiment (one year), the light applications of the relatively insoluble phosphates—applications which would add less than 0.007 per cent of P_2O_5 to a soil of medium texture—and the wide divergence in the yields of some of the check pots make these results hardly worthy of repetition.

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[1] Conn. Agr. Expt. Sta., 14th Ann. Rept., pp. 203–219 (1890); 19th Ann. Rept., pp. 122–127 (1895).

[2] Del. Agr. Expt. Sta., 6th Ann. Rept., pp. 193–202 (1893).

FLORIDA AND GEORGIA.

The Florida and Georgia State Experiment Stations have conducted no field experiments with ground raw rock[1] continuing beyond one year.

Because of the limited data given and the short duration of these experiments, their repetition is not justified.

ILLINOIS.

The Illinois Experiment Station recommends the use of ground raw rock phosphate as a fertilizer more strongly than any other station; in fact it is the only station which now advises the use of this material for general farming above any other phosphate carrier.

Hopkins first advocated the use of raw rock phosphate in 1903,[2] basing his recommendations on the work of the Ohio and Maryland stations. In most of the early published work of the Illinois station steamed bone meal was the phosphate carrier used,[3] though it is stated that on certain plots raw rock phosphate was substituted for the former. What plots these were, however, is not made clear.

In the summer of 1905[4] the results of some pot culture experiments conducted in order to compare the relative fertilizer values of raw rock phosphate and steamed bone meal were published.

The soil used was the gray silt loam of the Lower Illinois glaciation and wheat was the crop employed in the test. The pots were 10½ inches in diameter, but their height and cubic capacity are not given. The author states that equal money values of the two phosphates were employed in this test, that is, three times as much raw rock phosphate was added as bone meal. While the actual rate of application per pot and per acre are not given, it is presumed that the rate was the same as for the field experiments, viz, 200 pounds steamed bone meal per acre per annum and 600 pounds of raw rock phosphate. In certain pots the phosphate was turned under with a good growth of clover, in others with manure, and in still others with both clover and manure. The results of this comparative test are given in Table VIII, the yields being expressed both in grams per pot and bushels per acre.

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[1] Fla. Agr. Expt. Sta., Bul. No. 3, pp. 3–6 (1888); Bul. No. 10, pp. 21–27 (1890); Bul. No. 13, pp. 9–15 (1891); Bul. No. 82, p. 397 (1905); Press Bulletin No. 77 (1908). Ga. Agr. Expt. Sta., Bul. No. 2, pp. 35–37 (1889); Bul. No. 25 (1894); Bul. No. 26 (1894); Bul. No. 27 (1894).

[2] Ill. Agr. Expt. Sta., Circular No. 68, April, 1903.

[3] Ill. Agr. Expt. Sta., Bul. No. 99, March, 1905; Circular No. 96, July, 1905; Circular No. 97 (1905); Bul. No. 115 (1907).

[4] Ill. Agr. Expt. Sta., Circular No. 97 (1905).

TABLE VIII.—*Yields of wheat obtained in pot experiment to test the relative values of raw rock and steamed bone meal.*

Treatment.	Wheat yields.		Increase.
	Per pot.	Per acre.	Per acre.
	Grams.	*Bushels.*	*Bushels.*
None	10.0	27	....
Clover	16.3	43	16
Bone meal	14.7	39	12
Rock phosphate	14.2	38	11
Clover, bone meal	22.2	59	32
Clover, rock phosphate	23.3	62	35
Manure	16.5	44	17
Clover, manure	22.7	60	33
Manure, bone meal	19.4	52	25
Manure, rock phosphate	19.5	52	25
Clover, manure, bone meal	23.1	62	35
Clover, manure, rock phosphate	23.3	62	35
Potash	11.3	30	3
Clover, potash	18.4	49	22
Potash, bone meal	18.4	49	22
Potash, rock phosphate	18.2	49	22
Clover, potash, bone meal	21.9	58	31
Clover, potash, rock phosphate	21.9	58	31
Manure, potash	18.1	48	21
Clover, manure, potash	19.1	51	24
Manure, potash, bone meal	19.3	51	24
Manure, potash, rock phosphate	19.0	51	24
Clover, manure, potash, bone meal	25.3	67	40
Clover, manure, potash, rock phosphate	25.3	67	40
None	10.6	28	....

The beneficial effects of phosphate in this particular experiment are quite marked, even though the test was of comparatively short duration. The results obtained seem to indicate that raw rock phosphate (an equal money value) may be substituted for bone meal, particularly if the phosphate is applied with manure or turned under with a leguminous crop. In practically every instance the raw-rock pots equaled or surpassed the bone-meal pots with which they were directly comparable.

A number of papers by Hopkins[1] on the use of raw rock phosphate as a fertilizer appeared in 1908 and 1909, but the field work of the Illinois Station described in several of them is given more fully in subsequent publications. One of these circulars[2] is a reply to a pamphlet issued by the National Fertilizer Association advising against the use of raw rock phosphates. This circular shows that the quotations in this pamphlet from the Experiment Station bulletins are very incomplete and the conclusions drawn are unjustified.

In 1910, 1911, and 1912 the Illinois station issued several publications[3] on raw rock phosphates, but only one is quoted here, since the limited duration of the field work or the meager data given in the others hardly justify repetition.

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[1] Ill. Agr. Expt. Sta., Circular No. 116; Buls. Nos. 123 and 125 (1908); Circulars Nos. 127 and 130 (1909).

[2] Circular No. 127 (1909).

[3] Lloyd and Brooks, Bul. No. 144 (1910); Hopkins, C. G., Circular No. 141 (1910); Hopkins and Mann, Circular No. 149 (1911); Lloyd, Bul. No. 155 (1912).

In the early part of 1911 the Illinois station issued a circular by Hopkins and Mann.[1] In the first part Mann gives some results obtained with raw ground rock phosphates on his farm, the subdivisions of which were fairly well-drained fields of 85 acres each. Prior to the experiment a 4-year rotation of corn, corn, oats, and clover had been conducted on most of the fields for 30 years. It is not stated if the fields had received applications of lime or other fertilizers. Raw rock phosphate was applied at the rate of 1,000 pounds per acre every four years to the clover just before it was plowed under for the succeeding corn crop. The soil of this farm is largely the brown silt loam of the Early Wisconsin glaciation, commonly called the black prairie land of the corn belt.

The average results of five years' work are given below in Table IX.

TABLE IX.—*Five-year average yields per acre of corn, oats, and clover with and without the use of phosphate.*

Treatment.	Rotation.	Yield per acre.		
		Corn.	Oats.	Clover.
		Bushels.	*Bushels.*	*Tons.*
No fertilizer	2-year, corn and oats	34	32	....
Do	4-year, corn, corn, oats, and clover	54	47	1.5
Phosphate rock, 1,000 pounds every 4 years.	do	70	70	2.5

The results given in Table IX indicate strongly that medium applications of raw rock phosphate were very effective on this particular soil and farm. No field or plots were employed in this experiment, however, on which acid phosphate was applied, so a comparison of the relative merits of the two forms of phosphoric acid is not possible.

In this same circular Hopkins reviews the field work of the Illinois Experiment Station, but gives no detailed results obtained from the use of raw rock phosphate.

The results of seven years' work with raw rock phosphate on the Auburn experiment field, Sangamon County, were published by Hopkins, Mosier, Pettit, and Readhumer[2] in 1911.

A field of 10 acres located on a typical Middle Illinoisan brown silt loam was selected for this experiment. The previous history of the land, however, is not given, nor are any data presented showing the uniformity of the field. Two series of plots were employed, each series containing eight plots, four of which received raw rock phosphate and four no phosphate. A four-year rotation of corn, corn, oats, and clover was followed, corn being represented every year and oats and clover in alternate years.

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[1] Ill. Agr. Expt. Sta., Circular No. 149 (1911).

[2] Ill. Agr. Expt. Sta., Soil Rept. No. 4, pp. 7–9 (1912).

While it is stated that raw rock phosphate was applied at the rate of 1 ton per acre at the beginning of the experiment, it is not clear if there were any subsequent applications during the remaining six years of the experiment. No other commercial fertilizers were employed in this test; therefore the data allows no comparison of the relative values of the different phosphates.

All of the plots of this experiment field, with the exception of two, received applications of organic matter either in the form of crop residues or as farm manure.

In Table X the results obtained on eight plots of each series are given.

TABLE X.—*Average yields per acre from two series of plots, Auburn field (1905–1911).*

Treatment.	Corn, 7 crops.	Oats, 3 crops.	Clover, 2 crops.
	Bushels.	*Bushels.*	*Tons.*
Raw rock phosphate	51.9	45.3	2.16
Check	46.2	38.2	1.66
Average gain for raw rock	5.7	7.1	0.50

In commenting on this experiment Hopkins and his coworkers state that "on the whole, the data from favorable seasons strongly indicate a cumulative or increasing effect from the phosphate treatment, as we have reason to expect and as is shown in the latest crops of corn, oats, and clover, the increase amounting to about 25 per cent for oats, 34 per cent for corn, and 48 per cent for clover."

Hopkins[1] also published a paper in 1912 entitled "Shall We Use Complete Commercial Fertilizers in the Corn Belt?" in which he quotes the work of the Indiana and Ohio Experiment Stations with a view to showing that complete mixed fertilizers are inferior and much more expensive than the simple phosphate carriers, and that raw ground rock is the most economic form of phosphoric acid. No data from the Illinois Experiment Station farms are contained in this circular.

In 1913 Hopkins[2] published a paper entitled "Bread from Stones," which consists of a description of an impoverished farm in southern Illinois which the author has made productive by the so-called Illinois system of permanent fertility. The particular tract considered in this paper is a 40-acre field which had been agriculturally abandoned for five years prior to the experiment. During the 10 years prior to 1913, in which year the results reported were obtained, the field was cropped with a 6-year rotation, including 1 year each of corn, oats (or cowpeas), and wheat, and 3 years of meadow and pasture with clover and timothy.

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[1] Ill. Agr. Expt. Sta., Circular No. 165 (1912).

[2] Ill. Agr. Expt. Sta., Circular No. 168 (1913).

The figures obtained seem very favorable to the use of heavy applications (2 tons) of raw rock phosphate, but they are the yields of only one year. A comparison of the yields obtained therefore with and without the addition of raw rock phosphate is probably justified, although the land treated with phosphate rock received twice as much limestone as the plot on which no phosphate was applied. It is possible that the additional amount of lime which this tract received had considerable influence on the large increase in yield.

In the fall of 1913 Hopkins, Mosier, Pettit, and Fisher[1] reported in detail nine-year results of an experiment begun at Galesburg, Ill., in 1904. The soil of this experiment field is the brown silt loam prairie soil of the Upper Illinois glaciation. The field was divided into three series of plots, each series containing 20 plots of one-fifth acre each. A six-year rotation was followed. The previous history of the experiment field is not given.

At the beginning of the experiment limestone was applied to the first 15 plots of each series at the rate of 1,300 pounds per acre, and again to the same plots in either 1912 or 1913 at the rate of 4 tons per acre. In 1904 the first applications of raw ground rock phosphate were made, but the regular plan of this experiment which was to apply 1½ tons per acre of raw ground phosphate rock every six years before plowing for corn was not fully underway on all series of plots until 1906. One hundred pounds of potassium sulphate per acre was applied annually.

It was planned to study the use of phosphate rock, both in grain farming and live-stock farming. In the grain-farming system crop residues are returned to the various plots in proportion to the production of each and in the live-stock system all produce (or its equivalent) is used for feed and bedding and the manure returned to the plots in proportion to their yields during the preceding rotation. In this particular experiment, however, these two systems were not in operation on all series until 1911 and 1912. The average yields of the various crops during the nine years of the experiment are given in Table XI.

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[1] Ill. Agr. Expt. Sta., Soil Rept. No. 7 (1913).

TABLE XI.—*Average of results of nine years' work on three series of plots at Galesburg, Ill.—Six-year rotation employed, consisting of corn, corn, oats, wheat, clover, and timothy.*

Treatment.	Average yield per acre.				
	Corn, 9 years.	Oats, 5 years.	Wheat, 5 years.	Clover, 4 years.	Timothy, 4 years.
	Bushels.	*Bushels.*	*Bushels.*	*Tons.*	*Tons.*
Lime	65.66	48.24	27.98	1.75	1.81
Residues, lime	70.16	47.08	31.16	[1] .63	[2] 1.43
Manure, lime	77.21	48.34	29.54	2.19	1.90
Cover crop, manure, lime	76.68	50.20	31.06	1.90	1.96
Lime	71.64	49.50	30.66	2.03	1.96
Lime, phosphate rock	78.57	54.64	34.66	2.40	2.18
Residues, lime, phosphate rock	79.68	50.76	35.22	[1] .90	[2] 1.50
Manure, lime, phosphate rock	81.38	56.80	33.30	2.41	2.11
Cover crop, manure, lime, phosphate rock	82.93	53.56	35.32	2.31	2.27
Lime	73.01	47.28	28.92	1.81	2.05
Lime, phosphate rock, potash	80.89	53.48	34.46	2.53	2.58
Residues, lime, phosphate rock, potash	81.68	52.72	34.74	[1] 1.40	[2] 1.87
Manure, lime, phosphate rock, potash	81.37	56.36	32.46	2.77	2.20
Cover crop, manure, lime, phosphate rock, potash	83.94	55.50	33.96	2.73	2.26
Lime	74.23	49.60	27.90	1.82	2.10
Residues	72.32	49.42	28.82	[1] .82	[2] 1.67
Residues, phosphate rock	76.21	51.62	33.78	[1] .85	[2] 1.80
Residues, phosphate rock, potash	78.38	48.44	36.46	[1] 1.51	[2] 2.33
Residues, lime, nitrogen, phosphate rock, potash	81.59	56.18	35.95	[1] 1.21	[2] 2.83
None	70.82	51.98	29.04	1.55	2.08

[1] One crop only. [2] Average of three crops.

While the results given in Table XI are favorable to the use of raw rock phosphate they are not tabulated in a manner which brings out the true effect of this material. Manure was applied only after the experiment had been under way for four years, and the residue (or grain farming) system also was not fully in operation for some years. The average yields of the plots on which "manure" and "residues" were apparently applied therefore include the results of years in which no organic matter was used.

For more detailed figures on this experiment the reader is referred to Soil Report No. 7.

Later this year (1913) the same authors[1] published the results obtained with raw rock phosphate in two complete rotations (nine years) on the Fairfield experiment field, Wayne County, Ill. The soil of this experiment field is the common upland type of southern Illinois, consisting of a gray silt loam on dense clay. The history of the field is not given.

The experiment field was divided into four tracts of 10 acres each, "one half of the field, or 20 acres, is tile drained while the other half has only the ordinary surface drainage. On both the tiled and untiled land grain farming is practiced on one half and live-stock farming on the other half. A part of each of these divisions is treated with 2 tons of limestone and 1 ton of ground phosphate rock per acre every four years." No other commercial fertilizers were used. A four-year rotation was practiced on this field, consisting of corn, soy beans, wheat, and clover, each crop being grown every year on one of the four tracts. The average results obtained in nine years for each crop on the tiled and untiled land are given in Table XII, which is compiled from four tables given in Soil Report No. 8 of the Illinois station.

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[1] Ill. Agr. Expt. Sta., Soil Rept. No. 8 (1913).

TABLE XII.—*Average yields of corn, soy beans, wheat, and clover obtained on four series of plots at Fairfield, Ill., in an experiment conducted for nine years (1905–1913, inclusive).*

Treatment.	Average yield per acre.					
	Corn, 8 years.	Soy beans, 6 years.	Wheat, 7 years.	Clover, 6 years.	Oats, 1 year.	Cowpeas, 4 years.
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
Residues, lime, phosphate rock	36.58	8.23	13.79	0.67	35.8	6.08
Crop residues	28.90	6.28	4.17	.45	27.9	5.10
				Tons.		
Farm manure	35.54	6.02	5.21	0.57	32.5	5.68
Manure, lime, phosphate rock	46.91	9.09	18.03	1.61	38.7	7.53
				Bushels.		
Organic manures, lime, phosphate rock	41.86	8.67	15.90	0.82	37.2	6.80
Organic manures	32.21	6.16	4.69	.48	30.2	5.40
Increase due to lime and phosphate rock	9.65	2.51	11.21	.34	7.0	1.75

The authors state that the first four years of this experiment should be regarded as preliminary, partly because of the impossibility of obtaining full benefit from such treatments during the first rotation period, and also because the system of returning manure and crop residues in proportion to the yields produced was not begun until the first rotation was completed. But even taking the average yields of the various crops during both the first and second rotations, it will be seen that the plots treated with large amounts of raw-rock phosphate in connection with lime and organic manures produced considerably larger crops than those receiving no phosphate. The effect of the phosphate, however, was apparently more marked during the second rotation period, as can be seen by referring to the more detailed figures given in Soil Report No. 8 of the Illinois station.

Two experiments with raw-rock phosphate conducted over a period of five years were reported by Hopkins[1] in 1915.

One field at Ewing, Franklin County, consists of a gray silt loam on compact clay (prairie soil), the other at Raleigh, Saline County, is situated on a yellow-gray silt loam of the common upland timber type. The previous history of the fields is not given, however, nor are any data presented showing the uniformity of the fields or the size of the plots into which they were divided. Each field contained 4 series of 10 plots each, and since a four-year rotation of wheat, a legume, oats, and corn was followed, each crop was grown every year. Both live-stock and grain systems of farming were practiced on each farm.

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[1] Ill. Agr. Expt. Sta., Circular No 181 (1915).

At the beginning of these experiments limestone was applied on the plots indicated at the rate of 5 tons per acre at Ewing and 6 tons per acre at Raleigh; no further applications were made during the first five years of the experiment. Rock phosphate (finely ground) was applied at the rate of from 500 to 2,000 pounds per acre on the different series and kainit at rates varying from 200 to 800 pounds per acre, with subsequent applications every four years. It is not stated, however, which plots received the maximum and which the minimum amounts of these materials.

The average yield of each crop during the five years of the experiment is given below in Tables XIII and XIV.

TABLE XIII.—*Average results of five years' work on four series of plots at Ewing, Franklin County—Four-year rotation, consisting of wheat, cowpeas (or other legume), oats, and corn.*

Treatment.	Average yield per acre.					
	Wheat, 5 years.	Cowpeas, 3 years.	Clover, 1 year.	Soy beans, 1 year.	Oats, 5 years.	Corn, 5 years.
	Bushels.	*Tons.*	*Ton.*	*Ton.*	*Bushels.*	*Bushels.*
None	5.1	0.63	0.20	0.27	14.3	16.4
Manure	6.7	.52	.24	.23	19.8	23.3
Manure, lime	12.0	.88	.40	.47	23.0	28.9
Manure, lime, phosphate rock	13.7	.98	.81	.53	25.0	30.3
				Bushels.		
None	4.3	[1]1.46	.19	2.0	14.6	18.0
		Bushels.	*Bushels.*			
Residues	4.1	1.2	.00	2.3	16.4	18.7
Residues, lime	12.4	2.4	.50	4.0	25.4	29.7
Residues, lime, phosphate rock	14.0	3.2	1.08	4.0	24.0	28.4
Residues, lime, phosphate rock, potash	20.7	4.0	.75	4.2	27.2	31.7
			Ton.			
None	5.7	1.3	0.31	2.0	16.9	20.0

[1] One year only.

TABLE XIV.—*Average results of five years' work on four series of plots at Raleigh, Saline County—Four-year rotation, consisting of wheat, cowpeas (or other legume), oats, and corn.*

Treatment.	Average yield per acre.					
	Wheat, 5 years.	Cowpeas, 2 years.	Clover, 2 years.	Soy beans, 1 year.	Oats, 5 years.	Corn, 5 years.
	Bushels.	*Tons.*	*Ton.*	*Ton.*	*Bushels.*	*Bushels.*
None	8.6	2.3	0.33	0.28	11.7	17.2
Manure	7.4	1.8	.33	.30	11.7	24.3
Manure, lime	16.5	4.2	.67	.26	19.9	34.9
Manure, lime, phosphate rock	17.8	3.9	.68	.23	19.0	33.8
				Bushels.		
None	6.9	1.7	[1].23	.7	10.2	16.6
Residues	8.4	Turned.	Turned.	2.5	12.8	21.1
Residues, lime	18.6	Turned.	Turned.	2.5	19.7	31.3
Residues, lime, phosphate rock	20.7	Turned.	Turned.	2.7	20.0	33.0
Residues, lime, phosphate rock, potash	21.9	Turned.	Turned.	1.8	21.1	34.3
None	7.4	[1]1.1	([2])	.7	12.7	16.4

[1] One year only.

[2] No weight.

The average yields of the various crops as given in Tables XIII and XIV show little or no benefit from the application of phosphate rock, and where the plots so treated do show an average increase for certain crops this increase is practically no greater than the difference between the yields of the check plots. In an experiment of comparatively short duration, however, it is hardly fair to the difficultly soluble material (such as raw rock phosphate) to average the results as has been done in the above tables, since the figures so obtained give no idea of the cumulative effect of the phosphate treatments. As a matter of fact in these experiments the average financial returns from the raw-rock plots during the last two years were over twice as great as in the first three years, seeming to indicate that increasing amounts of organic matter and more thorough distribution of the phosphate were having an important influence in rendering the latter more effective in the soil. The author also points out the facts that the wheat crop in 1912 was a failure throughout the State and that the droughts in 1913 and 1914 were probably more severe than ever known in two consecutive years in the southern part of the State.

In January, 1916, Hopkins, Mosier, Van Alstine, and Garrett[1] reported the results of a number of experiments with raw rock phosphate which included 11 years' work on the Rockford field and 4 years' work on the Mount Morris field. Raw rock phosphate was the only phosphate fertilizer used in these experiments except what was contained in the manure and crop residues returned to the land.

The Rockford experiment field is located about 3 miles from the city of that name in Winnebago County, Ill. The soil of the field is described by the authors as a brown silt loam of the Iowan glaciation. No data are presented showing the relative fertility of the various plots nor is any previous history of the field given in this report. The field, however, was divided into four tracts, which were further subdivided into 20 plots of one-tenth acre each. A four-year rotation consisting of corn, corn, oats, and clover (with soy beans substituted in case of failure of the latter) was begun in 1904, each crop being grown every year on one of the four series of plots. It was planned to practice both grain and live-stock farming systems on this field, but neither system was fully under way until the later years of the experiment. In 1905, however, a legume cover crop was turned under on the plots indicated in three of the series and in 1908 a second growth of clover was turned under on the fourth series for the 1909 crop. Manure was applied on the plots indicated once at the rate of 4 tons per acre. Since 1909 it has been applied according to the live-stock farming system already described. Ground limestone was applied to plots 1 to 15 at the rate of 1,300 pounds per acre in 1906 and again in 1913 to the same plots at the rate of 4 tons per acre. Raw rock phosphate was applied to the plots indicated at the rate of 1 ton per acre every four years and potash in the form of potassium sulphate was applied at the rate of 400 pounds per acre every four years.[1]

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[1] Ill. Agr. Expt. Sta., Soil Rept. No. 12 (1916).

The average results of 11 years with four crops is given in Table XV.

TABLE XV.—*Average results of 11 years' work on four fields at Rockford, Ill.—Four-year rotation, consisting of corn, corn, oats, and clover.*

Treatment.	Average yield per acre.				
	Corn, 11 years.	Oats, 11 years.	Clover, 7 years.	Soy beans, 3 years.	Timothy, 1 year.
	Bushels.	*Bushels.*	*Tons.*	*Bushels.*	*Tons.*
Lime	54.64	57.98	1.83	9.65	1.65
Residues, lime	60.75	61.18	[1] 1.22	10.67	1.66
Manure, lime	68.84	60.76	1.96	14.89	1.65
Cover crop, manure, lime	66.65	59.50	2.04	14.66	1.59
Lime	58.83	54.90	1.91	10.90	1.59
Lime, phosphate rock	61.94	61.59	2.14	11.94	1.44
Residues, lime, phosphate rock	66.44	59.85	[1] 1.96	14.19	1.52
Manure, lime, phosphate rock	71.71	62.22	2.22	18.64	1.47
Cover crop, manure, lime, phosphate rock	69.69	61.86	2.26	19.69	1.45
Lime	57.03	57.18	1.84	16.78	1.47
Lime, phosphate rock, potash	69.73	60.86	2.36	13.02	1.57
Residues, lime, potash, phosphate rock	69.82	61.72	[1] 2.00	13.48	1.53
Manure, lime, potash, phosphate rock	71.75	59.73	2.38	18.44	1.43
Cover crop, manure, lime, potash, phosphate rock	71.80	62.89	2.45	22.30	1.41
Lime	60.19	56.30	1.85	11.13	1.62
Residues	64.40	60.16	[1] 1.94	13.10	1.65
Residues, phosphate rock	67.30	61.70	[1] 1.98	12.63	1.62
Residues, phosphate rock, potash	69.51	63.78	[1] 1.94	12.01	1.45
Residues, lime, nitrogen, potash, phosphate rock	73.25	68.82	[1] 2.08	13.16	2.46
None	54.72	58.83	1.89	10.34	1.40

[1] Average of three years only.

Just as in the case of several other experiments the results as reported here fail to show the cumulative effect of the phosphate treatments; but even taking the average yield of each crop for the entire period the plots on which raw rock phosphate was applied show on the whole considerably better yields than those receiving similar treatments, but no phosphate. By referring to the original tables in Soil Report No. 12 of the Illinois station, which gives the results of each year in detail, it will be seen that the plots receiving organic manures and raw rock phosphate were on the whole considerably more productive during the later than during the earlier years of the experiment, indicating very strongly that the effectiveness of the raw rock phosphate was increasing.

The Mount Morris experiment field[2] is located in Ogle County on a brown silt loam prairie soil. Only the results of four years on one series of plots and the results of two years on another series have been thus far reported, so they are not repeated in detail.

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[1] At the beginning of the experiment, however, potassium sulphate was not applied to each series in like quantity

[2] Ill. Expt. Sta., Soil Rept. No. 12, pp. 18–20 (1916).

Two experiment fields have been established at Urbana[1] to test out the fertilizer value of raw rock phosphate in both grain and live-stock farming systems. One field is on what is known as the "North Farm" and one on the "South Farm." The soil of both fields is the typical brown silt loam prairie land of that region.

The field on the North Farm was in three tracts, which after 20 years or more of pasturing had grown corn in 1895, 1896, and 1897 (when careful records were kept of the yields produced) and had then been cropped with clover and grass on one tract, oats on another, and oats, cowpeas, and corn on the third until 1901. The yields obtained in this preliminary period are not reported in Soil Report No. 12. It is probable, however, that the tracts were not at that time divided into plots, so the relative natural fertility of the 10 plots into which each series was divided for the subsequent experiment is not known.

From 1902 up to the close of 1910 a three-year rotation of corn, oats, and hay was followed, and in 1911 two more series of plots were introduced and a four-year rotation of wheat, corn, oats, and clover (or soy beans) was followed on four series of plots for five years, while on the fifth series alfalfa was grown for five years.

From 1902 to 1908, inclusive, phosphate was applied annually as steamed bone meal at the rate of 200 pounds per acre, but since 1908 one-half of each phosphate plot has been treated with ground raw rock at the rate of 600 pounds per acre per annum—the practice being to add and plow under at one time enough for one complete rotation. Potash was applied at the annual rate of 100 pounds of potassium sulphate per acre.

In the following table only the average results obtained since the introduction of the phosphate-rock treatments (seven years) are given:

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[1] Ill. Agr. Expt. Sta., Soil Rept. No. 14, pp. 7–16, October (1916).

TABLE XVI.—*Three and five year average yields per acre of corn, oats, clover, wheat, soy beans, and alfalfa, obtained on North Farm, Urbana, Ill., 1908–1915, inclusive.*

Treatment.	Average yields per acre.								
	1908–1910			1911–1915					
	Corn, 3 years.	Oats, 3 years.	Clover, 3 years.	Wheat, 5 years.	Corn, 5 years.	Oats, 5 years.	Soy beans, 4 years.	Clover, 1 year.	Alfalfa, 5 years.
	Bush.	*Bush.*	*Tons.*	*Bush.*	*Bush.*	*Bush.*	*Tons.*	*Tons.*	*Tons.*
None	49.4	40.8	2.30	22.2	53.9	46.3	1.60	2.50	2.27
Crop residues	51.5	43.4	[1] (1.93)	23.5	56.4	47.8	[1] (21.3)	[1] (0.74)	1.85
Manure	69.3	46.2	2.53	24.8	63.6	54.6	1.68	2.20	1.68
Residues, lime	58.1	45.7	[1] (2.02)	25.0	59.2	49.7	[1] (20.7)	[1] (1.03)	1.72
Manure, lime	74.9	47.5	2.94	28.1	63.4	57.3	1.72	2.81	2.25
Residues, lime, phosphate rock, 600 pounds	83.8	54.5	[1] (2.64)	39.1	66.0	64.3	[1] (22.6)	[1] (2.48)	3.28
Manure, lime, phosphate rock, 600 pounds	86.6	55.4	4.17	38.3	67.6	64.9	1.92	4.04	3.25
Residues, lime, phosphate rock, potash	86.7	53.5	[1] (1.99)	38.2	63.7	64.5	[1] (24.2)	[1] (1.41)	3.22
Manure, lime, phosphate rock, potash	90.9	53.6	3.90	37.4	64.6	69.3	2.09	3.91	3.31
Manure, lime, phosphate rock	81.3	54.3	3.79	42.9	61.0	72.5	2.19	4.24	3.45

[1] Bushels of seed.

The plots receiving phosphate treatments in every instance gave substantially greater average yields than those on which no phosphate was applied. These increases, however, can not be entirely attributed to raw rock phosphate, since the previous applications of steamed bone meal no doubt influenced considerably the crop yields. The results of one or more additional rotations should be obtained before it is wise to draw conclusions from this experiment.

On the South Farm, at Urbana, a four-year rotation is practiced on two series of plots. Raw rock phosphate has been applied at the rate of 500 pounds per acre per annum and ground limestone at the rate of 8 tons per acre once in 1910 and 1911. Beginning in 1912 the subsequent applications of limestone were at the rate of 2 tons per acre every four years.

The average results of 12 years' work on two series of plots on the South Farm are given below in Table XVII.

TABLE XVII.—*Average annual yields of crops grown in a four-year rotation on two series of plots on South Farm, Urbana, Ill., 1903–1915, inclusive.*

Treatment.	Average yield per acre.				
	Corn, 7 years.	Oats, 7 years.	Wheat, 7 years.	Clover, 3 years.	Soy beans, 2 years.
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
Residues, phosphate rock	60.2	40.6	40.4	0.71	15.2
Residues, phosphate rock	59.1	39.5	38.7	1.15	14.9
Residues	50.6	35.9	28.5	1.30	13.0
				Tons.	*Tons.*
Manure	54.6	36.6	28.7	2.72	1.0
Manure, phosphate rock	59.1	38.8	41.2	3.94	1.3
Manure, phosphate rock	60.9	38.8	42.0	3.99	1.4

TABLE XVII.—*Average annual yields of crops grown in a four-year rotation on two series of plots on South Farm, Urbana, Ill., 1903–1915, inclusive*—Contd.

	3 years.	2 years.	3 years.	Not grown.	2 years.
					Bushels.
Residues, lime, phosphate rock[1]	62.4	53.6	47.9	....	13.7
Residues, lime, phosphate rock[1]	61.5	52.8	46.5	....	12.3
Residues[1]	53.8	42.7	28.6	....	10.7
					Tons.
Manure[1]	58.4	47.6	29.5	....	0.84
Manure, lime, phosphate rock[1]	63.0	48.5	49.4	....	1.17
Manure, lime, phosphate rock[1]	63.2	50.2	48.7	....	1.34

[1] Plots on which lime was applied were not introduced into the experiment until 1910.

The results of this experiment point very strongly to the conclusion that raw rock used in liberal amounts in connection with organic manures is effective in increasing crop yields. But like many other experiments no data are reported which allow one to determine the relative efficiency of raw rock and acid phosphate.

In April 1916 Hopkins[1] reported the results of three long-time experiments at Cutler, Odin, and Mascoutah, in southern Illinois. These are the only experiments reported by Hopkins of Illinois work comparing the fertilizer value of steamed bone, acid phosphate, ground raw rock phosphate, and basic slag. Crop residues were returned to the land and potash and lime applied. At Odin and Mascoutah only half of each plot was limed. Fertilizers were applied once during each rotation in sufficient quantity to supply annually 200 pounds bone, 333 pounds acid phosphate, 666 pounds raw rock, and 260 pounds slag (equal money values at that time). The results of the experiments are given below in Tables XVIII and XIX.

TABLE XVIII.—*Average yields of corn, oats, wheat, and hay in two long-time experiments.*

Treatment.	Odin field (1904–1915).			Mascoutah field (1904–1913).[2]		
	Corn, 3 crops.	Oats, 3 crops.	Hay, 6 crops.	Corn, 4 crops.	Oats, 2 crops.	Wheat, 2 crops.
	Bushels.	*Bushels.*	*Tons.*	*Bushels.*	*Bushels.*	*Bushels.*
Residues, lime, bone, potash	33.9	47.8	1.30	45.4	38.6	26.3
Residues, bone, potash	31.4	50.9	.94	48.6	42.6	25.9
Residues, lime, potash	26.7	43.9	1.07	38.9	37.2	23.6
Residues, potash	27.6	43.9	.64	39.7	27.3	22.6
Residues, lime, acid phosphate, potash	30.2	43.5	1.19	44.0	37.0	25.4
Residues, acid phosphate, potash	29.9	52.8	.77	40.2	42.2	25.7
Residues, lime, rock phosphate, potash	32.3	48.4	1.28	47.2	38.9	26.7
Residues, rock phosphate, potash	27.0	52.2	.72	45.6	37.4	26.2
Residues, lime, potash	27.3	48.1	1.12	38.4	40.5	25.1
Residues, potash	21.7	41.1	.61	38.6	31.0	20.7
Residues, lime, basic slag, potash	32.7	56.8	1.27	45.6	43.0	26.5
Residues, basic slag, potash	27.3	50.3	.78	47.8	33.8	25.8

[1] Ill. Agr. Expt. Sta. Circular No. 186, April, 1916.

[2] Crops of legumes turned under in 1908 and 1911.

TABLE XIX.—*Average yields of corn, wheat, legumes, and oats, Cutler field.*

Treatment.	Average yield per acre (1904–1915).			
	Corn, 4 crops.	Wheat, 3 crops.	Legumes, 1 crop.	Oats, 2 crops.
	Bushels.	*Bushels.*	*Tons.*	*Bushels.*
Residues, lime, bone, potash	34.9	25.1	2.74	27.1
Residues, lime, potash	38.4	16.9	2.11	31.6
Lime, potash	36.9	16.3	1.80	25.5
Residues, lime, acid phosphate, potash	36.0	28.7	2.52	28.8
Lime, acid phosphate, potash	37.1	26.6	2.40	31.8
Residues, lime, phosphate rock, potash	42.2	25.8	2.51	24.6
Lime, phosphate rock, potash	37.3	18.5	2.06	29.3

In almost every instance plots treated with ground raw rock phosphate gave noticeable increases in yield over the check plots, and at Odin and Mascoutah showed to better advantage than the acid phosphate plots. At Cutler the acid phosphate plots appeared to greater advantage. However, none of the phosphate treatments gave very large increases, and, as Hopkins says, "These investigations have shown that phosphorus is not the factor which first limits the crop yields on these southern Illinois soils, both limestone and organic matter being of greater initial importance." Owing to the adverse climatic conditions during the latter part of the experiment it is impossible to tell whether or not any cumulative effect can be attributed to the use of raw rock.

The data presented in the 12 field experiments with raw rock phosphate conducted by the Illinois station and considered here in detail point pretty strongly to the conclusion that this phosphate carrier increases crop yields very materially when applied liberally. Since raw rock was compared with other phosphates in only 3 of the 12 experiments, and on fields where phosphoric acid apparently was not the limiting factor, the work hardly appears to justify a comparison of the relative merits of the different phosphate carriers.

INDIANA.

The first mention of the use of raw rock phosphate as a fertilizer made by the Indiana Experiment Station was in 1896,[1] when phosphatic marl containing from 10 to 12 per cent of phosphoric acid was tried on two series of wheat plots of one-twentieth acre each. The short duration of this experiment (one year), however, and the little data presented make the results relatively unimportant.

Two experiments with raw rock phosphate were described by Goss[2] in 1907 and several others by Abbott and Conner[3] in 1912, but none of these were conducted for a period of more than four years, so the results are not considered in detail.

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[1] Ind. Agr. Expt. Sta., Bul. No. 61, p. 64 (1896).

[2] Ind. Agr. Expt. Sta., Circular No. 10, pp. 9–11 (1907).

[3] Ind. Agr. Expt. Sta., Bul. No. 155 (1912).

All the other experiments with raw rock phosphate conducted by the Indiana station are described and discussed by Wiancko and Conner[1] in a recent bulletin entitled "Acid Phosphate versus Raw Rock Phosphate as Fertilizer."

Two of these experiments, one at Littles, in Pike County, and the other at Scottsburg, Scott County, were begun at the same time (1905), and are similar in every respect. There are three series of plots of one-twentieth acre each, and a three-year rotation of corn, wheat, and clover has been practiced, so that each crop could be grown on one series every year. "When the clover failed cowpeas or soy beans were substituted. The land was plowed once in three years for corn, except when clover failed, when it was also plowed for soy beans or cowpeas. The wheat was drilled on disked corn stubble and the clover seeded on the wheat in the spring." The various fertilizers were all applied to the wheat in the first round of the rotation, the treatment being as follows: Manure at the rate of 10 tons per acre, raw rock at the rate of 1 ton per acre, and acid phosphate drilled with the wheat at the rate of 150 pounds per acre. After the first rotation manure was again applied at the same rate on every corn crop and acid phosphate on every wheat crop. A second ton of raw rock phosphate was applied for corn and cowpeas in 1911 and 1912. Both fields were limed in 1911 at the rate of 2 tons of finely ground limestone per acre. While there were three check plots in each of the three series, the various fertilizer materials were represented by only one plot in each series.

The field at Littles is nearly level with a slight slope running lengthwise of the plots. The soil is described as a yellowish brown silt loam of medium fertility. The phosphoric acid content as determined by analysis is 0.13 per cent.

The Scottsburg field is almost level on one series, but rises gradually through the two other series of plots. The soil is Volusia silt loam and is considered of low fertility. The total phosphoric acid content as determined by analysis is less than 0.1 per cent. The average yields of the three crops on both fields during the 10 years of the experiment are given in Tables XX and XXI.

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[1] Ind. Agr. Expt. Sta., Bull. No. 187, vol. 18 pp. 1055–1082 (1916).

TABLE XX.—*Average yields of corn, wheat, and legumes obtained in a 10-year experiment on three series of plots at Littles, Pike County, Ind. (1906–1915).*

Treatment.	Average yield per acre.				
	Corn, 8 crops.		Wheat, 10 crops.		Legume, 3 crops.
	Ear corn.	Stover.	Grain.	Straw.	Hay.
	Bushels.	*Pounds.*	*Bushels.*	*Pounds.*	*Pounds.*
Nothing	41.8	3,298	13.3	1,149	3,987
Acid phosphate, 150 pounds [1]	41.9	3,288	15.0	1,407	4,353
Rock phosphate, 1 ton	39.2	3,030	14.7	1,293	3,913
Nothing	37.7	2,990	13.7	1,122	3,767
Rock phosphate, 1 ton; [2] manure, 10 tons [1]	46.9	3,435	18.6	1,769	4,930
Manure, 10 tons [1]	47.4	3,698	18.4	1,769	4,043
Nothing	41.0	3,427	14.9	1,491	3,793

[1] Per rotation.

[2] Rock phosphate applied at the above rate twice during 10 years.

TABLE XXI.—*Average yields of corn, wheat, and legumes obtained in a 10-year experiment at Scottsburg, Scott County, Ind. (1906–1915).*

Treatment.	Average yield.				
	Corn, 8 crops.		Wheat, 10 crops.		Legume, 3 crops.
	Ear corn.	Stover.	Grain.	Straw.	Hay.
	Bushels.	*Pounds.*	*Bushels.*	*Pounds.*	*Pounds.*
Nothing	25.1	2,366	9.2	862	749
Acid phosphate, 150 pounds [1]	34.3	2,817	15.6	1,392	1,412
Rock phosphate, 1 ton [2]	40.4	2,988	13.9	1,311	1,396
Nothing	30.5	2,578	10.2	992	1,291
Rock phosphate, 1 ton; [2] manure, 10 tons [1]	51.2	4,114	20.8	2,138	3,151
Manure, 10 tons [1]	50.5	4,025	20.0	2,073	3,065
Nothing	30.5	2,583	10.4	1,061	1,523

[1] Per rotation.

[2] Rock phosphate applied at the above rate twice during 10 years.

The average results of 10 years' work on the Littles field are not very satisfactory, since the difference between the average yields of certain check plots is greater than the difference between the checks and the plots treated with phosphates. Moreover the yields of all crops (except the legumes) on some of the checks were practically as good and in some cases better than the yields on the plots treated with phosphates alone, indicating that the soil was not very responsive to phosphate treatments. Only in the case of the legume hay did acid phosphate seem appreciably more beneficial than raw rock; in fact, it was on this crop only that the former appeared at all effective. More significant increases in the yields of legumes were obtained, however, on plots receiving manure reenforced with phosphate rock.

On the Scottsburg field the effect of phosphate treatments seemed much more marked, the average yields of the fertilized plots being well above those of the checks. In this experiment the raw-rock plots gave average yields comparing favorably with those treated with acid phosphate.

The writers feel, however, that the method of application used in these experiments hardly admits of a fair comparison of the relative merits of ground raw rock and acid phosphate. Nearly three times the amount of money was invested in raw rock during the 10 years as in acid phosphate. This means that in order to show a profit comparing favorably with that obtained on the acid-phosphate plots the increases in yield from raw-rock plots must be three times as great. On a field showing little or no response to phosphate treatments (such as the Littles field) it appears to the writers unwise to attempt to compare the two forms of phosphoric acid when the rock-phosphate plot was so heavily handicapped. Considering now the Scottsburg experiment, the only instance where there is any significant difference shown between the yields of the plots receiving the two forms of phosphoric acid is in the corn crop, where the average yield of the raw-rock plot was considerably greater than that of the plot treated with acid phosphate.

Four other experiments with raw rock phosphate undertaken by the Indiana station are described in this same paper, but none of them cover a period of over four years, so they do not warrant detailed discussion.

The work of the Indiana station on the whole, while not conclusive, gives evidence of increased crop yields resulting from applications of raw rock phosphate. Under the conditions of the experiments any attempt to form conclusions concerning the relative merits of raw rock and acid phosphate seems unwarranted.

KENTUCKY.

The first data of the Kentucky station pertaining to the use of raw rock phosphate as a fertilizer were published in 1899.[1] They consisted of the results obtained from a one-year experiment with various phosphate carriers on wheat.

The same cooperator continued the experiment the following year,[2] but employed a different field and discontinued the application of ground rock phosphate. The results of this experiment are not repeated here.

In 1912 the Kentucky station in cooperation with the State Geological Survey published a paper[3] containing the results of three series of pot experiments with a yellow silt loam of rather low phosphate content. In series 1 and 3, pots of 4 gallons capacity were employed containing 30 pounds of soil each, and in series 2, pots one-half this size (2 gallons) containing 15 pounds of soil were used.

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[1] Ky. Agr. Expt. Sta. Bull. No. 83, pp. 35–38 (1899).

[2] Ky. Agr. Expt. Sta., Bul. No. 89 (1900).

[3] Ky. Agr. Expt. Sta., Bul. No. 162 (1912).

Series 1 was planted to tobacco the first year, followed by oats the second year. Series 2 was planted to clover the first year, followed the second year by tobacco. Series 3 was planted to wheat the first year and to clover the second year.

In each instance after the first crop was harvested the soil was dried, emptied out of the pots, mixed thoroughly with the fertilizers for the following crop, and then returned to the pots. The results of these experiments are given in part in Tables XXII, XXIII, and XXIV.

TABLE XXII.—*Yields of tobacco and oats obtained in pot tests with various fertilizers.*

SERIES I.—TOBACCO (4-GALLON POTS).

Fertilizer.	Application per pot.	Yield of stalks and leaves per pot.	Increase per pot.	Relative increase.
	Grams.	*Grams.*	*Grams.*	*Per cent.*
None	....	[1] 13.8	....	....
Limestone	15.0	12.0	−1.75	−12.7
Dissolved bone (24 per cent P_2O_5)	3.8	10.3	−3.75	−27.2
Rock phosphate	20.0	13.2	−0.55	− 4.5
Manure	35.0	9.7	−4.05	−29.4
Do Rock phosphate	35.0 20.0	10.3	−3.45	−25.1

SERIES I.—OATS (AFTER TOBACCO).

Fertilizer.	Application per pot.	Whole crop.		Grain.		
		Yields per pot.	Increase per pot.	Yield per pot.	Increase per pot.	Relative increase.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
None	....	[1] 47.5	....	[1] 10.1	....	....
Limestone	15.0	61.0	13.5	13.5	3.4	33.6
Dissolved bone (24 per cent P_2O_5)	3.7	83.0	35.5	15.0	4.9	48.5
Rock phosphate	20.0	68.5	21.0	13.4	3.3	32.7
Manure	35.0	93.5	46.0	16.5	6.4	63.4
Do Rock phosphate	35.0 20.0	84.0	36.5	15.4	5.3	52.4

[1] Average of 2 pots.

TABLE XXIII.—*Yields of clover and tobacco obtained in pot tests with various fertilizers.*

SERIES II.—CLOVER (2-GALLON POTS).

Fertilizer.	Application per pot.	Weight of three cuttings per pot.	Increase per pot.	Relative increase.
	Grams.	*Grams.*	*Grams.*	*Per cent.*
None	....	16.0	....	....
Limestone	7.5	20.4	4.4	27.5
Dissolved bone	1.9	32.1	16.1	100.6
Rock phosphate	10.0	30.8	14.8	92.5
Manure	17.5	25.7	9.7	60.6
Rock phosphate Manure	10.0 17.5	27.6	11.6	72.5

TABLE XXIII.—*Yields of clover and tobacco obtained in pot tests with various fertilizers*—Continued.

SERIES II.—TOBACCO (AFTER CLOVER).

Fertilizer.	Application per pot.	Stalks and leaves per pot.	Increase per pot.	Relative increase.
	Grams.	*Grams.*	*Grams.*	*Per cent.*
None		[1] 3.75		
Limestone	7.5	5.00	1.25	33.3
Dissolved bone	1.9	4.60	.85	22.7
Rock phosphate	10.0	7.40	3.65	97.3
Manure	17.5	9.50	5.75	153.3
Do.	17.5	7.60	3.85	102.4
Rock phosphate	10.0			

[1] Average of two pots.

TABLE XXIV.—*Yields of wheat and clover obtained in pot tests with various fertilizers.*

SERIES III.—WHEAT (4-GALLON POTS).

Fertilizer.	Application per pot.	Whole crop.		Grain.		
		Yield per pot.	Increase per pot.	Yield per pot.	Increase per pot.	Relative increase.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
None		[1] 34.9				
Dissolved bone	3.8	44.6	9.7	14.6	2.7	22.7
Rock phosphate	20.0	45.6	10.7	15.7	3.8	31.9
Manure	35.0	44.5	9.5	16.2	4.3	36.1
Do.	35.0	36.3	1.4	14.9	3.0	25.2
Rock phosphate	20.0					

SERIES III.—CLOVER (AFTER WHEAT).

Fertilizer.	Application per pot.	Weight of first cutting per pot.	Weight of second cutting per pot.	Total per pot.	Increase per pot.	Relative increase.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
None		[1] 13.8				
Dissolved bone	3.8	45.3	24.6	70.4	41.05	139.9
Rock phosphate	20.0	32.2	21.0	53.2	23.85	81.3
Manure	35.0	46.5	25.0	71.5	42.15	143.6
Do.	35.0	36.5	24.5	61.0	31.65	107.8
Rock phosphate	20.0					

[1] Average of two pots.

It will be noticed that the pots receiving applications of phosphates, whether water soluble or relatively insoluble, gave considerable increases in yield over the untreated pots, except in series I, where tobacco was grown the first year.

The soluble phosphate on the whole gave somewhat better yields than the ground rock, although the latter material was applied liberally. In the second year of series II, however, when tobacco was grown, the ground-rock pot gave a much greater yield than the pot treated with acid phosphate. Contrary to what one would expect, the pots treated with a mixture of rock phosphate and manure gave lower yields in nearly every case than those treated with manure alone. In three out of six cases ground rock alone exceeded a mixture of ground rock and manure.

In this publication the authors state that these experiments were to be continued, but no further results of the tests have yet been published.

In 1914 the Kentucky station, in a bulletin on "Alfalfa and Sweet Clover,"[1] gave the results obtained in a single season with these crops when treated with raw rock and acid phosphate, but since the work was not continued beyond one year and the data given are very limited the figures are not repeated.

In 1915 and 1916 Roberts[2] published the results of an experiment conducted at Burnside, Pulaski County, which had been running since 1908. The field used lies on a hillside of moderate slope. The soil consists of a badly worn limestone clay, very low in organic matter, which had produced poor crops for a long time; practically no manure had been returned to it for many years. In 1908, less than 3½ bushels of wheat per acre were produced on this field, although it had received 200 pounds per acre of an 8–2–2 fertilizer.

In the summer of 1908, after the wheat was harvested, the field was laid out in six plots of one-fourth acre each, and the following fertilizers were applied on the unbroken ground and plowed under: Phosphate rock, 2,000 pounds per acre; acid phosphate, 800 pounds per acre; muriate of potash, 400 pounds per acre. Cowpeas were then sown and later turned under. The plots were then planted to rye and vetch, and while the latter crop failed the rye made a good growth. In the case of both cowpeas and rye the acid phosphate plots gave greater yields.

No more fertilizer was applied until 1911, then a light dressing of manure was added to each plot, equivalent to what the corn and oats crops of each plot would make. In 1912 another such application of manure was added to the plots in addition to the same applications of fertilizer materials as in 1908. In the spring of 1914 a uniform dressing of nitrate of soda was applied to all plots because wheat was so backward. Manure was again added at the same rate as before in 1915, and potash and phosphates at one-fourth the rate previously employed.

The results of seven years' work are given in detail in Table XXV.

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[1] Ky. Agr. Expt. Sta., Bul. 178 (1914).
[2] Ky. Agr. Expt. Sta., Bul. No. 191 (1915); Bul. No. 199 (1916).

TABLE XXV.—*Results of seven years' work on Burnside experiment field (1909–1915).*

Fertilizer.	Application per acre.[1]	Yield per acre.						
		Corn, 1909.	Oats, 1910.	Clover, 1911.	Corn, 1912.	Soybean hay, 1913.	Wheat, 1914.	Corn, 1915.
	Pounds.	*Bushels.*	*Bushels.*	*Pounds.*	*Bushels.*	*Pounds.*	*Bushels.*	*Bushels.*
Rock phosphate Potash	2,000 400	3.8	9.3	2,436	32.9	1,688	11.9	34.8
Nothing		9.0	9.0	668	9.5	628	2.5	4.9
Acid phosphate Potash	800 400	14.3	11.9	2,168	45.7	2,272	19.2	46.6
Acid phosphate	800	17.7	13.6	2,328	43.5	2,112	18.1	50.9
Nothing[2]		20.4	14.0	1,292	30.3	1,176	5.1	18.5
Potash	400	11.9	10.5	764	17.6	560	1.7	5.3

[1] The fertilizers were applied at rate per acre stated in summer of 1908, again at the same rate in 1912, and at one-fourth the above rate in 1915.

[2] The station states that this plot should not be considered a check plot.

While the plot treated with raw rock phosphate and potash gave yields below and no better than the check plots in 1909 and 1910, respectively, from then on it forged ahead rapidly, indicating that the crops were benefited by the phosphate treatments after the latter became more thoroughly distributed in the soil through cultivation. The yields of the acid phosphate plots, however, greatly exceeded (in all but one instance) those of the raw-rock plot, even though the less soluble material added over four times as much phosphoric acid to the soil. While no data are given showing their relative natural fertility, it is said that the raw-rock plot was handicapped by being naturally less fertile than the other plots in the experiment field.

The results of six other experiments comparing acid phosphate with raw rock phosphate, conducted for periods of from three to four years in various parts of the State, are given by Roberts in this same bulletin. Their limited duration, however, coupled with the fact that the weather conditions were very bad during two of the years, render detailed considerations of the results unwarranted in this paper.

The data presented by the Kentucky station are insufficient to be conclusive, although the results of the field experiment cited did indicate that raw rock, while inferior to acid phosphate, increased crop yields after the lapse of a year or more.

LOUISIANA.

Of the 13 experiments with ground rock phosphate or "floats" carried on by the Louisiana Experiment Station, 10[1] were conducted through periods of from one to four years. These are not repeated in detail.

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[1] La. Agr. Expt. Sta., Buls. Nos. 3, 4, 6 (1886); 7, 8, 11 (1887); 14 (1888); 20 (1889); 28 (1890) (old series). Buls. Nos. 8 (1891); 14, 16 (1892); 26, 29 (1894) (new series).

In 1889, however, the North Louisiana Experiment Station, at Calhoun, La.,[1] began a five-year experiment to test the effect of various phosphatic fertilizers (alone and in combination with other materials) on cotton. The results were published year by year, but in no bulletin is there a table giving the complete results for all five years. They have been consolidated by the authors in Table XXVI.

Neither the size of the plots nor the character of the soil used in this experiment are mentioned, but the soil at the station is said to be on the whole sandy. The field was plowed during the winter of each year, the fertilizer drilled in in the spring, and the seed planted shortly afterwards. The crop was cultivated and hoed several times during each growing season.

The climatic conditions during the third and fifth years are not described, but during 1889, and in July and August of 1890, droughts somewhat handicapped the crops. In 1892 late planting and excessive rains seriously affected the yields for that year.

Table XXVI.—*Results obtained in the growing of cotton on plot No. 2 (Calhoun, La.) (1889–1893).*

Fertilizer.	Application per acre.	Yield per acre of seed cotton.				
		1889	1890	1891	1892	1893
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Gypsum	80	1,520	1,810	1,860	730	1,250
Dissolved bone black	160	1,630	1,770	1,870	820	1,240
Basal mixture [1]	600	1,970	1,800	1,780	710	1,540
Basal mixture [1]	600	[2] 1,990	[2] 2,133	[2] 2,215	[2] 920	[2] 1,645
Dissolved bone black	160 320					
Gypsum	80	1,390	1,620	1,710	760	1,320
Acid phosphate	160	1,350	1,680	1,620	780	1,160
Basal mixture [1]	600	1,720	1,870	1,700	920	1,450
No manure		1,010	1,210	1,380	520	960
Basal mixture [1]	600	[2] 1,950	[2] 1,760	[2] 1,735	[2] 680	[2] 1,285
Acid phosphate	160 320					
Bone meal	160	770	1,180	1,330	590	890
Basal mixture [1]	600	1,170	1,370	1,480	660	1,170
Basal mixture [1]	600	[2] 1,305	[2] 1,335	[2] 1,545	[2] 700	[2] 1,130
Bone meal	160 320					
Floats	160	480	690	1,030	460	610
Basal mixture [1]	600	920	1,100	1,190	560	1,100
Basal mixture [1]	600	[2] 835	[2] 1,015	[2] 1,255	[2] 680	[2] 880
Floats	160 320					
No manure		330	630	730	380	470

[1] Basal mixture = 480 pounds cotton-seed meal and 200 pounds kainit.
[2] Average of two plots.

It is apparent that the plots of this experimental field were far from uniform. Moreover, small applications of raw rock phosphate (160 pounds per acre) used on continual cotton without incorporating more organic matter in the soil than was supplied in the basal mixture employed in this experiment could hardly be expected to produce marked effects on the crop yield.

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[1] La. Agr. Expt. Sta., Bul. No. 27 (1889) (old series). Buls. Nos. 8 (1891); 16 (1892); 26, 29 (1894) (new series).

In 1889 the North Louisiana Experiment Station began a number of experiments with corn.[1] One of these had for its object the testing of the effect of various phosphatic fertilizers alone and in combination on the crop yields. This experiment was carried on for five years, but the raw phosphates were not introduced until the second year. The results obtained each year were published in separate bulletins,[2] but for the sake of brevity and clearness they are here all incorporated in one table. As in the case of the cotton experiments carried on at this same station, the size of the plots employed is not mentioned, and the only description given of the soil is that it was poor.

The land was plowed during the winter and fertilized in the spring. The corn was planted in rows 5 feet wide and 3 feet apart in the drill. The complete results are given below in Table XXVII.

TABLE XXVII.—*Results obtained at Calhoun, La., in the growing of corn (1889–1893).*

Fertilizer.	Application per acre.	Yield per acre of corn.				
		1889	1890	1891	1892	1893
	Pounds.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels*
Gypsum	56	26.69	21.00	15.00	13.60	16.00
Dissolved bone black	112	28.00	23.00	12.75	25.20	19.60
Basal mixture	336	25.00	28.00	14.25	32.80	22.00
Do	420	22.00	23.14	12.75	25.60	21.80
Dissolved bone black	112					
Gypsum	56	14.49	14.42	6.00	10.80	8.80
Acid phosphate	112	13.00	12.17	5.25	17.20	8.80
Basal mixture	420	20.00	18.25	10.50	18.80	16.80
No manure	....	12.00	11.00	4.50	8.40	7.60
Basal mixture	420	22.19	18.13	13.88	23.20	24.00
Acid phosphate	112					
Bone meal	112	14.10	13.00	10.50	11.20	17.60
Basal mixture	420	17.00	20.32	13.50	29.40	21.60
Do	420	17.50	20.78	17.25	31.20	24.80
Bone meal	112					
South Carolina floats	112	....	9.00	6.75	13.60	15.60
Basal mixture	420	....	22.00	14.25	28.40	20.40
Do	420	....	21.75	15.75	29.80	22.40
South Carolina floats	112	....				
No manure	....	....	9.10	6.75	14.00	10.50

The wider differences between the yields of the various plots receiving "basal mixture" show that this field was not of uniform fertility.

A careful study of Table XXVII will also show that the soil seemed to respond much more readily to the nitrogenous than to the phosphatic fertilizers, but the applications of the latter were rather light, particularly for the relatively insoluble phosphates. With the exception of those treated with bone or dissolved bone black, the plots on which phosphates were applied alone gave on the whole little or no increase in yield over the unfertilized plots. While floats alone gave no increase in yield for the first three years of the experiment, the crop produced the fourth year on this plot exceeded the no-fertilizer plots by a considerable margin, indicating that there was a cumulative effect. When the phosphates were used in connection with the "basal mixture," however, their effect seemed more marked. A comparison of the phosphate-basal-mixture plots shows that the bone meal and floats gave on the whole higher yields than either dissolved bone black or acid phosphate, but these differences are negligible when compared with the differences in yield between the various "basal-mixture" plots.

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[1] La. Agr. Expt. Sta. Bul. No. 27 (1890).

[2] La. Agr. Expt. Sta., Buls. Nos. 8, 16, 21 29 (new series).

A fertilizer experiment with sugar cane begun at Audubon in 1890, was continued for 10 years, and in 1900 the averages of the results obtained during that period were published.[1] There were, however, during this period only eight crops of cane harvested.

The land selected for this experiment was part of Audubon Park and had not been under cultivation for years. It had grown the native deep-rooted grasses which had sometimes been cropped for hay, but more frequently allowed to decompose on the fields. The soil, therefore, was rich in organic matter and might be considered at the outset almost new. No description is given of the soil type. The land was tile-drained. The fertilizers were applied only in those years in which cane was grown and raw rock phosphate was not introduced into the experiment until 1891. The acidulated phosphates were applied at the rate of 250 pounds per acre when used alone, but when used in conjunction with potash and nitrogen carriers they were applied at two rates, namely, 250 pounds and 500 pounds per acre. The less soluble phosphates, bone, basic slag, and South Carolina "floats" were applied at the rate of 500 pounds per acre throughout.

The results are given in Table XXVIII.

TABLE XXVIII.—*Eight-year average results obtained at Audubon Park, La., in the growing of sugar cane (1890–1900).*

Fertilizer and annual application per acre.[2]	Average yield per acre.	
	Cane.	Sucrose in juice.
	Tons.	*Per cent.*
Dissolved bone black, 250 pounds	29.88	11.77
Dissolved bone black, 250 and 500 pounds; basal mixture,[3] 330 pounds	[4] 29.52	[4] 10.64
Basal mixture,[3] 330 pounds	28.19	10.84
Acid phosphate, 250 pounds	26.12	11.55
Acid phosphate, 250 and 500 pounds; basal mixture,[3] 330 pounds	[4] 29.55	[4] 11.04
No fertilizer	25.10	11.59
Bone black, 500 pounds	27.26	11.37
Bone black, 500 pounds; basal mixture,[3] 330 pounds	27.59	11.35
Slag meal, 500 pounds	27.68	11.62
Slag meal, 500 pounds; basal mixture,[3] 330 pounds	30.44	11.82
Basal mixture,[3] 330 pounds	28.45	11.70
South Carolina floats, 500 pounds	26.76	12.04
South Carolina floats, 500 pounds; basal mixture,[3] 330 pounds	29.19	11.67
No fertilizer	25.38	12.29
Bone meal, 500 pounds	26.73	12.26
Bone meal, 500 pounds; sulphate of potash, 100 pounds	26.03	12.34
Bone meal, 500 pounds; basal mixture,[3] 330 pounds	27.44	11.96

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[1] La. Agr. Expt. Sta., Bul. No. 59 (new series) (1900).

[2] Fertilizer applications made only in years cane was grown (8 years).

[3] Basal mixture = 230 pounds ammonium sulphate and 100 pounds potassium sulphate.

[4] Average of two plots.

The results given in Table XXVIII indicate strongly that medium applications of phosphate, either soluble or relatively insoluble, produced appreciable increases in the yield of sugar cane. The yields on the whole were slightly in favor of the acidulated phosphates, but the average yield of the plot treated with a combination of basic slag and "basal mixture" exceeded those of all the other plots. The plot treated with dissolved bone black alone gave the next highest yield, followed by the plots receiving mixtures of the acidulated phosphates (dissolved bone black and acid phosphate) and "basal mixture." The yield of the floats-basal mixture plot, however, was so close to that of the latter two that the difference is well within experimental error. When applied alone, South Carolina "floats" and bone meal apparently gave about equal results, the yields being greater than that of the acid-phosphate (alone) plot.

In two out of the three experiments of the Louisiana station here cited, the applications of raw rock were so light and the evidence points so strongly to the lack of uniformity in the experiment fields that the results have little value. In the third experiment, however, where the phosphates were applied more liberally the increased yields of sugar cane obtained from the insoluble-phosphate treatments compared favorably with those from the soluble-phosphate plots.

MAINE.

Owing to the limited data presented and their short duration (from one to two years), six[1] of the nine experiments with raw rock phosphate conducted by the Maine Experiment Station are not considered in this paper.

In 1895[2] the Maine station published the results of two field experiments with various forms of phosphoric acid. One was conducted for nine years and the other for seven years.

The first experiment was conducted on a 2-acre field which was divided into 36 plots containing one-twentieth acre each. The soil of this field was a clay loam and said to be quite uniform throughout. Before the sod was broken for the experiment in 1885 the field had grown three heavy crops of grass, previously to which it had received a liberal application of stable manure and unleached wood ashes. In 1885, without any further addition of fertilizer, the field produced a crop of barley.

Fertilizers were applied only five times during the nine years of this experiment, no applications being made in 1888, 1890, 1891, and

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[1] Me. Agr. Expt. Sta., Ann. Repts. for 1888, pp. 64–66 (1889); 1889, pp. 140–143 (1890); 1890 (1891); 1891 (1892).

[2] Me. Agr. Expt. Sta. Ann. Rept. for 1894 (1895).

1892. Six plots received no fertilizer treatments whatever. The remaining 30 plots received 10 different fertilizer treatments, the same treatment being applied to three plots in each case. The average annual results obtained from each fertilizer treatment are given in Table XXIX.

TABLE XXIX.—*Results of nine years of field work in the growing of various crops (1886–1894).*

Fertilizer.	Application, per acre.	Yield per acre (average of 3 plots).								
		1886	1887	1888[1]	1889	1890[1]	1891[1]	1892[1]	1893	1894
		Oats.	Oats.	Hay.	Fallow.	Peas.	Oats.	Peas.	Corn.[2]	Corn.[2]
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*		*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
No fertilizer	....	3,664	2,000	2,566	....	1,406	1,892	1,216	395	749
Dissolved bone back Potassium chloride Ammonium sulphate	400 100 200	5,900	3,400	2,434	....	1,850	2,332	1,124	1,415	2,926
Ground bone Potassium chloride Ammonium sulphate	360 100 200	5,420	2,566	2,800	....	1,922	2,466	1,072	1,326	3,038
Ground South Carolina rock Potassium chloride Ammonium sulphate	300 100 200	5,052	3,100	2,566	....	1,762	1,936	860	1,076	2,631
Stable manure	40,000	5,266	3,074	4,010	....	2,644	3,288	1,976	2,931	3,562
No fertilizer	....	3,968	2,400	1,634	....	1,618	2,068	1,180	366	978
Dissolved bone black	400	4,512	2,100	2,166	....	1,774	2,666	668	576	1,280
Do Potassium chloride	400 100	4,906	2,634	2,066	....	1,978	2,668	736	1,486	2,532
Dissolved bone blaek Potassium chloride Ammonium sulphate	200 50 60	4,732	2,834	2,166	....	1,738	2,496	848	942	1,982
Dissolved bone black Potassium chloride Ammonium sulphate	300 100 120	5,640	3,500	1,766	....	1,694	2,700	1,092	967	2,598
Dissolved bone black Potassium chloride Ammonium sulphate	400 150 180	6,034	3,834	2,374	....	1,778	2,666	1,084	2,046	3,427
Potassium chloride Ammonium sulphate	100 200	4,500	2,700	2,234	....	1,422	2,000	1,180	905	1,879

[1] No fertilizers.

[2] Air dried.

In this experiment the plots treated with stable manure gave on the whole better results than any of the other plots. The plots receiving heavy applications of dissolved bone black in combination with potash and nitrogen carriers came next, followed by those treated with a mixture of bone meal, potash, and nitrogen. The plots treated with ground raw rock phosphate gave a lower average increase than the other phosphates, but produced in all but two instances a distinct gain over the plots fertilized with potash and nitrogen carriers alone.

While the applications of dissolved bone black (300 and 400 pounds per acre) employed in this experiment are considered comparatively heavy for such a soluble phosphate, an application of 300 pounds of ground raw rock is a light application for such a relatively insoluble material. Moreover, in describing this experiment there is nothing to indicate that the soil was well supplied with organic matter, which would aid in rendering the less soluble phosphate more effective. The conditions, therefore, were much more favorable to the water soluble phosphates than to raw ground rock.

The results of the other long-time experiment published in this same report[1] cover a period of seven years. This second experiment was conducted on a larger scale than that just described and had two objects in view: First, to determine the possibility of maintaining soil fertility by the use of commercial fertilizers, and second, to determine the comparative value of raw rock phosphate and acid phosphate.

A 10-acre field, the soil of which was a clay loam and excellent grass land, was selected for this experiment, and divided into four plots of 2½ acres each. For two years (1888 and 1889) no fertilizers whatever were applied to any of the plots, grass being grown in order to determine their relative natural fertility. Fertilizers were applied only once during the seven years of the experiment (in 1890), so the results after that year show in a measure the residual effects of the various fertilizer treatments.

The results of this experiment are given below in Table XXX.

TABLE XXX.—*Results obtained on plots of two and one-half acres each, in the growing of various crops (1888–1894).*

Fertilizer.	Application per acre.	1888-89	1890[1]	1891	1892	1893	1894
		Hay.[1]	Barley and peas.	Oats, Total.	Barley, hay.	Summer tilled.	Oats, dry matter.[2]
	Loads.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Stable manure	20	2,542	2,208	3,818	3,444	....	1,894
	Pounds.						
Ground South Carolina rock	1,000	2,416	1,712	2,981	2,324	....	2,453
Nitrate of soda	66						
Ammonium sulphate	16						
Potassium chloride	100						
Acid phosphate	500	2,082	1,422	2,972	1,930	....	1,734
Nitrate of soda	66						
Ammonium sulphate	16						
Potassium chloride	100						
No manure	....	2,510	1,118	2,480	1,161	....	957

[1] Fertilizer applied in 1890 only.
[2] Oats were cut before maturing and used for silage.

The indications are that the plot which was afterwards treated with acid phosphate was naturally less fertile than the other plots of the experiment field. Contrary to what one would expect the raw rock phosphate was apparently as effective as acid phosphate during the first year of its application, yet the following year (if the apparent relative natural fertility of the two plots be taken into consideration) the acid-phosphate plot appeared to greater advantage since its yield nearly equaled that of the raw-rock plot. In 1892 and 1894 (particularly in the latter year), however, the plot receiving raw rock phosphate two and four years previously forged ahead very noticeably.

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[1] Idem., p. 28–32.

In 1896 Merrill[1] published the results of the box experiments begun by Ballentine[2] a number of years before and continued after the latter's death. The work was carried on still further, however, and all the results published by Merrill[3] in 1899.

This experiment was undertaken in order to determine the relative availability of various phosphates and also to test the ability of some of the common crops to obtain phosphoric acid from these different sources. The work was conducted in one of the greenhouses, and the plants grown in wooden boxes 14 inches square and 12 inches deep. The boxes were filled to within 1½ inches of the top with 120 pounds of sand. The sand was taken from a knoll near the river, at a depth of 3 or 4 feet, and was nearly free from organic matter. Traces of phosphoric acid were present. Before filling the boxes, the sand was carefully screened and mixed thoroughly with the various fertilizers.

Eighteen species of plants were grown, representing seven orders: (1) peas, horse beans, clover, and alfalfa (Leguminosæ); (2) turnips, rutabagas, cauliflower, and kohlrabi (Cruciferæ); (3) barley, oats, and timothy (Gramineæ); (4) tomatoes and potatoes (Solanaceæ); (5) carrots and parsnips (Umbelliferæ); (6) buckwheat (Polygonaceæ); and (7) sunflower (Compositæ).

It was planned to carry each plant through three periods of growth, but the clover would not mature in the time it took for the other plants to do so, hence only two crops were grown. The sunflower and buckwheat did not thrive under the conditions of the experiment; and, after a single trial, were replaced by carrots and parsnips, which were grown for the two following periods.

In each period 12 boxes were employed for each kind of plant. The boxes were divided into three sets of four each, the various phosphate treatments as well as the checks being run in triplicate.

No attempt was made at pollination, and since but few insects were present during the growth of the plants, the fruiting was very irregular. As soon as the plants seemed to have attained their maximum development they were harvested, dried, weighed, and the total amount of dried matter determined for each crop grown.

The phosphates used in this experiment were acid phosphate, Redonda phosphate (phosphate of iron and alumina) made largely citrate soluble by ignition, and Florida finely ground phosphate rock

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[1] Me. Agr. Exp. Sta. Ann. Rept. for 1895, p. 10–14 (1896).

[2] Me. Agr. Exp. Sta. Ann. Rept. for 1893 (1894).

[3] Me. Agr. Exp. Sta. Ann. Rept. for 1898 (1899).

(floats). These materials were added in such amounts that they each furnished 6.58 grams of phosphoric acid, an amount sufficient to add only 0.01 per cent of P_2O_5. In addition to the phosphate each fertilized box received 10 grams of sodium nitrate, 5 grams of potassium chloride, and 5 grams of magnesium sulphate. In the boxes where the Redonda was used 10 grams of calcium sulphate was also added.

The average production for a single period is shown in Table XXXI.

TABLE XXXI.—*Relative weights of dry matter obtained in box experiments with various phosphates.*

Crop.	Weight.	Phosphate treatment.	Crop.	Weight.
	Grams.			*Grams.*
Peas	167	Acid phosphate	Tomatoes	135
	122	Floats		92
	94	Redonda		79
	87	No phosphate		36
Horse beans	269	Acid phosphate	Potatoes	260
	128	Floats		187
	118	Redonda		156
	86	No phosphate		151
Clover	217	Acid phosphate	Carrots	214
	169	Floats		141
	126	Redonda		140
	83	No phosphate		135
Alfalfa	107	Acid phosphate	Parsnips	237
	97	Floats		151
	87	Redonda		155
	90	No phosphate		163
Turnips	222	Acid phosphate	Buckwheat	107
	202	Floats		54
	187	Redonda		51
	119	No phosphate		37
Rutabagas	152	Acid phosphate	Sunflowers	101
	145	Floats		14
	122	Redonda		15
	64	No phosphate		11
Cauliflower	176	Acid phosphate	Turnips (roots)	100
	167	Floats		70
	107	Redonda		90
	62	No phosphate		44
Kohlrabi	232	Acid phosphate	Rutabagas (roots)	62
	209	Floats		47
	172	Redonda		32
	130	No phosphate		16
Barley	338	Acid phosphate	Cauliflower	50
	171	Floats		19
	186	Redonda		....
	146	No phosphate		....
Corn	218	Acid phosphate	Kohlrabi	153
	85	Floats		129
	98	Redonda		92
	31	No phosphate		60
Potatoes (tubers)	185	Acid phosphate	Oats	662
	131	Floats		307
	140	Redonda		380
	115	No phosphate		319
Carrots (roots)	173	Acid phosphate	Timothy	410
	109	Floats		323
	113	Redonda		346
	102	No phosphate		353
Parsnips (roots)	196	Acid phosphate		
	115	Floats		
	114	Redonda		
	120	No phosphate		

While all the phosphate treatments appeared to be beneficial, in every case the boxes receiving acid phosphate gave greater yields than those treated with the Redonda or raw Florida rock. The gain was especially marked in the case of the Gramineæ family, three members of which—barley, corn, and oats—yielded nearly double the amount produced by either the floats or Redonda phosphate.

The fact that the same quantity of phosphoric acid was applied in all forms and that this application was light for the relatively insoluble phosphates is distinctly unfavorable to these phosphates. Moreover, it is stated that the sand used in this experiment was nearly free from organic matter, which fact would also be unfavorable to the raw rock phosphate. It is not surprising, therefore, that greater yields were obtained from the use of the soluble phosphate in these experiments.

The results of both the field and greenhouse experiments conducted by the Maine Station indicate strongly that applications of raw rock phosphate increase the yields of many crops and that this material is more effective when applied liberally. The data, however, are insufficient to be conclusive as to the relative merits of raw rock and acid phosphate.

MARYLAND.

The first work conducted by the Maryland station to test the fertilizer value of the relatively insoluble phosphates consisted of several experiments[1] on corn, wheat, sweet potatoes, and tomatoes, but in all these experiments the natural phosphates employed were guanos from islands in the Caribbean Sea. According to the analyses of these guanos they contained a certain amount of available (so called) phosphoric acid, and in some instances a small percentage of nitrogen, so it is hardly fair to place them in the same class with the amorphous phosphates of Florida, South Carolina, and Tennessee. For this reason the results of these experiments are not included in this paper.

The results of five years' work in testing the relative values of various carriers of lime were published by the station in 1906.[2] While finely ground South Carolina rock was used on one of the plots, no comparison can be made of its value with that of acid phosphate in this experiment since all the plots, with the exception of the checks received in addition to the lime carriers applications of a complete fertilizer. Under these conditions lime in the form of oxide, hydrate or carbonate produced yields as great as that obtained from lime combined with phosphoric acid in ground rock phosphate. It is worthy of note, however, that the plot receiving ground rock phosphate in addition to a complete fertilizer produced greater yields than the plot treated with complete fertilizer alone.

The results of work carried on for 12 consecutive years with various kinds of phosphate were published by the Maryland station in

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[1] Md. Agr. Expt. Sta., Bul. No. 5 (1889); Special Bul. (Fair edition) (1889); Buls. Nos. 10 (1890); 14 (1891).

[2] Md. Agr. Expt. Sta., Bul. No. 110 (1906).

1907.[1] These experiments had several objects in view but were conducted chiefly to test the relative fertilizer value of the soluble and the relatively insoluble phosphates on corn, wheat, and hay.

The field used is said to be fairly level, well drained, and quite uniform throughout. The soil was moderately stiff clay. The history of the cropping of this field before the experiment was undertaken is as follows:

In 1888 the land grew a poor crop of weeds and grass which was plowed down. The land was then sown to wheat which was harvested in 1889; in 1890 and 1891 the field was in grass, and in 1892 corn was planted. The land was fallowed in 1893, but in 1894 it was again planted to wheat in which both timothy and clover were sown.

In 1895[2] the field was divided into 22 plots of one-tenth acre each and planted to corn, crimson clover being sown subsequently in the corn on plots 1 to 12, and rye on plots 18 to 22. These latter crops were plowed under the following spring. In 1896, 1897, and 1898[3] corn was again grown under the same conditions. In 1899 a crop of wheat was harvested followed by hay in 1900 and 1901. In 1902 and 1903 corn was again grown followed by wheat in 1904 and hay in 1905.

The various phosphates were applied in such quantities as to furnish equal amounts of phosphoric acid to the soil. It appears that the phosphate applications were made every year except in 1899, 1900, 1901, and 1905 when wheat and hay were the crops grown.

There were four check (no phosphate) plots employed in this experiment, on two of which a green crop (rye or clover) was turned under subsequent to the growing of corn. In the tables given below only the average of these four plots is reported. Three plots each were treated with the following phosphates in quantities supplying 150 pounds of P_2O_5 per acre, raw bone meal, basic slag, ground South Carolina raw rock and Florida soft phosphate. Two each of these plots had a green crop turned under in six out of the 12 years of the experiment, in order to study the effect of decaying organic matter on the availability of these relatively insoluble phosphates. In the following tables the average of the three plots is taken in each instance, although in some cases the organic matter present apparently increased the effectiveness of the phosphate treatment.

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[2] Md. Agr. Expt. Sta., Bul. No. 114 (1907).

[3] Md. Agr. Expt. Sta., 8th Ann. Rept., p. 226 (1895).

[3] The corn crop in 1898 was a failure.

TABLE XXXII.—*Yields of corn (grain and fodder) per acre obtained (1895–1906).*

Fertilizer.	Application per acre.	1895		1896		1897		1902		1903		1906		Average of 6 crops of grain.	Average of 5 crops of fodder.
		Grain.	Fodder.	Grain.	Fodder.	Grain.	Fodder.	Grain.	Fodder.	Grain.	Fodder.	Grain.	Fodder.		
	Pounds.	*Bushels.*	*Pounds.*	*Bushels.*	*Pounds.*	*Bushels.*	*Pounds.*	*Bushels.*	*Pounds.*	*Bushels.*	*Pounds.*	*Bushels.*	*Pounds.*	*Bushels.*	*Pounds.*
Double superphosphate	319	46.0	2,860	40.3	2,100	57.9	3,020	45.7	2,600	17.6	750	39.9	2,000	41.2	2,516
Dissolved bone black	735	38.7	2,700	37.4	2,200	51.1	2,930	46.4	2,600	21.8	785	46.1	2,300	40.3	2,546
Dissolved South Carolina rock	1,000	39.0	2,400	35.8	2,340	43.6	2,810	43.6	2,650	16.2	....	44.6	2,050	37.1	2,450
Reverted phosphate of lime	370	35.8	2,420	37.0	2,060	47.7	2,920	46.4	2,650	29.3	....	45.8	2,150	40.3	2,400
Nothing [1]	....	43.4	2,480	41.9	2,130	46.2	2,778	37.7	2,350	35.4	1,847	41.3	2,088	40.9	2,365
Reverted iron and aluminum phosphate	370	45.4	2,940	43.2	2,400	64.9	3,330	50.0	2,950	18.0	....	42.7	2,200	44.0	2,764
Bone black	514	36.9	2,340	41.6	2,160	58.1	3,070	43.2	2,550	17.8	....	34.1	1,700	38.9	2,364
Raw bone meal [2]	667	44.8	2,460	44.2	2,400	54.3	3,046	46.4	3,067	21.5	1,400	26.0	1,517	39.5	2,498
Slag phosphate [2]	920	43.7	2,340	43.9	2,713	49.8	2,927	44.0	3,000	22.6	1,050	30.6	1,633	39.1	2,523
Ground South Carolina rock [2]	530	45.2	2,447	43.8	2,227	43.7	2,920	42.5	2,707	23.6	1,367	39.5	2,150	39.7	2,490
Florida soft phosphate [2]	560	46.7	2,547	40.7	1,773	44.6	2,957	46.7	3,167	35.4	1,967	41.2	2,050	42.6	2,499

[1] The yields of the checks are the average of four plots, two of which had a green crop turned under every year corn was grown.

[2] The yields are the average obtained on three plots, two of which had a green crop turned under.

TABLE XXXIII.—*Yields*[1] *of wheat and hay per acre obtained (1895–1906).*

Fertilizer.	Application per acre.[2]	1899		1900	1901	1904		1905	Average yields.		
		Wheat.		Hay.	Hay.	Wheat.		Hay.	Wheat.		Hay.
		Grain.	Straw.			Grain.	Straw.		Grain.	Straw.	
	Pounds.	*Bushels.*	*Pounds.*	*Pounds.*	*Pounds.*	*Bushels.*	*Pounds.*	*Pounds.*	*Bushels.*	*Pounds.*	*Pounds.*
Double superphosphate	319	36.0	4,140	3,900	4,300	12.2	1,070	2,400	24.1	2,605	3,533
Dissolved bone black	735	37.1	4,375	4,200	4,310	12.0	775	2,500	24.6	2,575	3,670
Dissolved South Carolina rock	1,000	37.0	2,930	4,950	4,050	12.3	760	2,400	24.6	1,845	3,800
Reverted phosphate of lime	370	31.6	3,550	4,250	4,650	12.8	1,030	3,400	22.2	2,290	4,100
Nothing	....	21.8	2,601	3,838	3,812	3.1	340	850	12.5	1,471	2,833
Reverted iron and aluminum phosphate	370	34.6	3,170	4,800	6,450	12.2	1,070	2,900	23.4	2,120	4,717
Bone black	514	25.6	3,415	4,000	4,350	9.3	590	2,700	17.5	2,003	3,683
Raw bone meal	667	35.0	3,903	3,867	4,200	12.3	980	3,016	23.7	2,442	3,694
Slag phosphate	920	36.2	4,195	3,550	4,517	9.3	775	3,633	22.8	2,485	3,900
Ground South Carolina rock	530	31.5	3,509	4,217	4,533	8.7	777	2,966	20.1	2,143	3,905
Florida soft phosphate	560	30.0	3,134	4,050	4,517	9.7	643	2,760	19.9	1,886	3,776

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[1] The yield of the check is the average of four plots, two of which had a green crop turned under; and the yields of the treated plots are the average of three plots, two of which had a green crop turned under in connection with the phosphates.

[2] Phosphates were applied in 1895, 1896, 1897, 1898, 1900, 1901, 1902, 1903, 1905, 1906.

The results on corn given in Table XXXII are rather inconclusive, even though they represent the crops of six years. The average production of the no-phosphate plots was in many instances greater than that of the plots receiving phosphate treatments. Only in the cases of the plots treated with reverted phosphate of iron and aluminum were there fairly consistent increases obtained over the check plots. In 1903 the average yield of the check plots exceeded that of any of the others except the Florida soft phosphate plots and equaled the average yield of these.

The yields of the various soluble phosphate plots were very inconsistent. For instance, the plot treated with double acid phosphate gave on the average an increase in yield over and above the no-phosphate plots, yet the plot treated with dissolved South Carolina rock (ordinary acid phosphate), which was applied in such quantities as to furnish the same amount of phosphoric acid, gave a yield considerably below the average of the check plots.

The results obtained on the hay crop (Table XXXIII), however, were more consistent. With the exception of the first crop of the dissolved South Carolina rock plot, the yields from the less soluble phosphate plots were greater than from the water soluble phosphate plots, and in nearly every instance the yields of the treated plots were considerably greater than those of the checks. Here, again, the reverted phosphate of iron and aluminum gave the highest yields.

Although the conditions of this experiment were apparently more favorable to the soluble phosphates the results indicate that for corn and hay the relatively insoluble phosphates of iron and aluminum in a very finely divided or precipitated condition, were more effective than the former.

In the case of the two crops of wheat grown on these same plots the opposite results were obtained (Table XXXIII). The yields of the soluble phosphate plots in most instances exceeded the yields of the relatively insoluble phosphate plots quite appreciably, and all the treated plots gave considerable increases in yield over the check plots.

Regarding the influence of decaying organic matter in the soil, the turning under of rye seemed to increase somewhat the effectiveness of the insoluble phosphates, but the plots on which clover was grown and subsequently turned gave on the average smaller yields than similar plots receiving no organic matter.

In studying the results of these experiments two questions naturally arise. First, how uniform was the soil of the various plots, and, second, what would have been the effect of applications of lime?

Another five-year experiment undertaken by the Maryland station some time after the one just described and discussed, gives consideration to these points. In this later experiment an attempt was made to determine the relative natural fertility of the various plots on the experimental field by uniform cultivation, and the growing of wheat and hay for three years preceding the application of the phosphates.

The yields of the various plots during these three years are given in Table XXXIV.

TABLE XXXIV.—*Relative productive capacity of plots when receiving uniform treatment.*

Plot number.	Wheat, 1899.		Hay.		Total of 3 crops.	Average yearly yield.
	Grain.	Straw.	1900	1901		
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1	1,535	2,800	4,050	4,010	12,395	4,132
2	1,415	2,630	3,500	3,150	10,695	3,565
3	1,835	3,565	3,600	3,900	12,900	4,300
4	2,130	4,070	4,500	3,750	14,450	4,817
5	2,120	3,980	4,550	4,050	14,700	4,900
6	2,100	4,300	3,450	3,750	13,600	4,533
7	2,190	4,310	4,350	4,100	14,950	4,983
8	2,165	4,100	2,500	4,400	13,165	4,388

The figures given in Table XXXIV indicate strongly that this field was not of uniform fertility. They show how the relative yields of similarly treated plots may vary from year to year independent of fertilizer treatment, thus making it not only unwise but well nigh impossible to draw final conclusions from field work covering only a short period of time.

The yields of the same plots after treatment with the various phosphates are given in Table XXXV. Besides introducing other varieties of phosphates into this experiment, the effect of liming on the soil was studied by employing two soluble phosphate plots, one of which received in addition to acid phosphate a liberal application of lime.

TABLE XXXV.—*Yields of plots (reduced to yields per acre) when fertilized (1902–1906).*

Plot number.	Phosphate treatment, 150 pounds P_2O_5 per acre in the following forms.	1902		1903		1904		1905	1906		Total yield of 5 crops.	Average yield.
		Corn.		Corn.		Wheat.		Hay.	Corn.			
		Grain.	Fodder.	Grain.	Fodder.	Grain.	Straw.		Grain.	Fodder.		
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1	South Carolina phosphate rock	3,500	3,000	2,410	1,550	350	400	1,600	3,485	3,000	19,235	3,847
2	Dissolved South Carolina rock	3,190	3,000	2,185	1,450	660	740	2,450	2,960	2,500	19,135	3,827
3	Dissolved South Carolina rock and lime	3,800	3,050	2,690	1,600	415	485	3,000	2,485	2,000	19,535	3,907
4	Nothing	3,670	3,050	3,570	2,300	245	555	1,950	3,000	2,250	20,590	4,118
5	Tennessee phosphate	4,050	3,000	3,910	2,500	550	600	3,200	3,660	2,650	24,120	4,824
6	Florida soft phosphate	3,390	3,300	4,355	2,850	665	1,335	3,450	3,920	2,500	25,765	5,153
7	Virginia phosphate	3,250	2,300	4,875	3,250	600	900	4,500	3,800	2,900	26,385	5,277
8	Precipitated phosphate	3,300	2,800	4,195	2,200	840	1,310	4,200	3,240	2,400	24,485	4,897

In order to see at a glance the apparent relative values of the various phosphates used in this experiment, the Maryland station compiled a table in which the yields given in Tables XXXIV and XXXV were reduced to a percentage basis, taking the yield of the Virginia phosphate plot as 100. The results are given in Table XXXVI. It will be noted that the average production of the different plots after the application of the phosphates was less than before the treatments, but since the greatest decrease in yield was on the check plots, it is assumed that the phosphates had a beneficial effect.

The figures in the column headed "Relative increase" represent the average relative increases of the various phosphate plots over the check plot.

TABLE XXXVI.—*Relative yields and average influence of different forms of phosphoric acid, expressed in percentages.*

Phosphate treatment, 150 pounds P_2O_5 per acre, in the following forms:	Rate of yield before experiment.	Rate of yield during experiment.	Difference.	Relative increase.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Ground South Carolina rock	83	73	−10	10
Dissolved South Carolina rock	72	72	0	20
Dissolved South Carolina rock and lime	86	74	−12	8
Check (no phosphate)	97	77	−20	0
Ground Tennessee rock	98	91	− 6	14
Ground Florida rock	91	98	+ 7	27
Ground Virginia rock	100	100	0	20
Precipitated phosphate	88	93	+ 5	25

Apparently the greatest effect was produced by the Florida soft phosphate and the precipitated phosphate treatments. The Virginia phosphate (which, it is said, was largely a phosphate of aluminum) and the acid phosphate (without lime) came next with the same relative increase. Contrary to popular belief the application of lime in connection with acid phosphate did not in this experiment appear to be beneficial.

The Maryland station results as a whole may be said to indicate that applications of the relatively insoluble phosphates in a finely divided or precipitated condition increase crop yields as effectively in some instances as the more soluble phosphates.

MASSACHUSETTS.

In 1890 the Massachusetts station undertook an experiment[1] to compare the relative fertilizer merits of acid phosphate (dissolved bone black) and some of the less soluble phosphates when the various forms were applied in quantities representing at that time equal money values.

The field selected for this experiment was quite level and had been used as a meadow up to 1887. The soil was a fair sandy loam, but said to be well worn. In order to exhaust the field still further of its natural fertility, corn, Hungarian hay, and legumes were grown in 1888 and 1889 without the application of any fertilizer whatever, but no attempt was made to determine whether or not the field was uniform.

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[1] Mass. Agr. Expt. Sta., 8th, 9th, 10th, and 11th Ann. Repts. Hatch Agr. Expt. Sta., 14th Ann. Rept. (1902).

In the spring of 1890 the plots (1/6 acre each) were laid out and each one furnished annually with what were thought to be optimum quantities of potash and nitrogen. The following applications of phosphates were made to the various plots annually for four years:

Plot No. 1:	Basic (phosphatic) slag	(19.04 per cent P_2O_5)	=127 pounds
2:	Mona guano	(21.88 per cent P_2O_5)	=128 pounds
3:	Ground Florida rock phosphate	(21.72 per cent P_2O_5)	=129 pounds
4:	Ground South Carolina phosphate	(27.57 per cent P_2O_5)	=131 pounds
5:	Dissolved bone black	(15.82 per cent P_2O_5)	= 78 pounds

In 1894 the phosphate applications were discontinued in order to study their residual effects but the potash and nitrogen applications were increased 50 per cent. A check or no phosphate plot was introduced in 1895, and the experiment continued until 1902 (12 years).

In Table XXXVII the yields of the various crops during the entire period of the experiment are given. Apparently no details of the corn crop of 1898, and the oat crop of 1899, have been published, and the yields of the check plot during 1895 and 1896 could not be found in the records.

TABLE XXXVII.—*Yields per acre of various crops during twelve years of experiment (1890–1901).*

Fertilizer.	Annual[1] application per acre.	1890	1891	1892	1893	1894	1895
		Potatoes.	Wheat.	Serradella.	Corn.	Barley.	Rye.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Basic slag	762	9,600	2,280	24,420	9,960	2,910	4,170
Mona guano	768	8,490	2,040	20,460	8,286	2,430	3,780
Ground Florida rock	774	9,000	1,290	16,500	8,082	1,740	2,298
Ground South Carolina rock	786	10,980	2,280	18,660	8,814	2,760	4,554
Dissolved bone black	468	12,720	2,430	17,520	7,932	2,340	3,750
No phosphate	....	....	....	....	....	....	Not given

Fertilizer.	Annual[1] application per acre.	1896	1897	1898	1899	1900	1901
		Soy beans (beans).	Turnips (roots).	Corn.	Oats.	Cabbage.[2]	Oats (grain).
	Pounds.	*Pounds.*	*Pounds.*			*Pounds.*	*Bushels.*
Basic slag	762	1,524	11,220	(3)	(3)	1,980	100
Mona guano	768	1,398	21,930	(3)	(3)	1,500	84
Ground Florida rock	774	1,572	4,920	(3)	(3)	60	67
Ground South Carolina rock	786	1,512	11,790	(3)	(3)	3,300	95
Dissolved bone black	468	1,482	9,714	(3)	(3)	1,560	79
No phosphate	....	Not given	4,980	(3)	(3)	48	87

[1] Phosphates applied during the first four years only.

[2] The weights given represent cabbages which weighed over 2½ pounds.

[3] No detailed yields given.

It will be seen that while dissolved bone black led for the first two years, during the remainder of the experiment several of the relatively insoluble phosphates forged ahead, phosphatic slag being first, South Carolina floats second, and Mona guano third. Florida ground rock phosphate, however, gave relatively poor yields when compared with the plot treated with South Carolina floats.

In Table XXXVIII the average relative rank of the various plots from the beginning of the experiment, until it was discontinued in 1902, are expressed on a percentage basis.

TABLE XXXVIII.—*Average relative rank of the plots treated with various phosphates*[1] *(equal money values) during the 12 years*[2] *of the experiment.*

Treatment.	Per cent.
Basic (phosphatic) slag	100.0
Ground South Carolina rock	92.6
Dissolved bone black	89.7
Mona guano	87.3
Florida phosphate rock	71.1
No phosphate (6 years)	55.4

[1] No phosphates applied after the third year.

[2] The crop of Swedish turnips grown in 1897 is not included, since it was damaged by disease.

While the basic slag and ground South Carolina phosphate plots led all the rest in this experiment, the dissolved bone-black plot was not far behind.

Brooks[1] considers that the phosphates in this experiment were applied in a very irrational manner and in a way favorable to the relatively insoluble varieties, but even under these conditions he concludes that the data do not prove that the less soluble were more effective than the readily soluble phosphates since the yields from the Mona guano and Florida phosphate plots (particularly the latter) were materially less than that of the acid phosphate plot.

While the writers feel that the data obtained are hardly sufficiently consistent to warrant a definite conclusion regarding the relative merits of the various phosphate carriers, nevertheless they are of the opinion that the method of applying phosphates in this experiment was considerably more logical from an economic standpoint than that employed in the subsequent experiment of the Massachusetts station upon which Brooks lays much greater stress.

In 1897 a second experiment[2] was undertaken by the Massachusetts station to test the fertilizer value of various phosphates when they were applied in such amounts as to furnish equal quantities of phosphoric acid to the soil.

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[1] Mass. Agr. Expt. Sta., Bul. No. 163, pp. 147–148 (1915).

[2] Hatch Agr. Expt. Sta., 10th Ann. Rept. (1898).

A summary and discussion of this experiment after 18 years' work was published by Brooks[1] in 1915.

The field selected for this experiment was fairly level, but while the soil as a whole was a medium silt loam, the plots varied somewhat in physical character. Moreover, the fertility of the various plots (as determined by a crop of corn grown the year previous to the application of fertilizer) was apparently not uniform. The field had been in grass for a number of years preceding the experiment, and had received annually moderate top dressings of chemical fertilizers. In 1896, the field was plowed, divided into 13 plots of $\frac{1}{8}$ acre each, and planted to corn without the addition of any fertilizer whatever, in order to determine the relative natural fertility of the various plots. The corn was cut green and weighed. Apparently there has been some confusion in the statement of the yields of corn obtained in this preliminary test, for in Public Document No. 33,[2] published shortly after the experiment was begun the yields obtained on plots 1 to 13, inclusive, are in the reverse order from those given in Brooks's summary of this experiment published in Bulletin No. 162. On account of this confusion the yields obtained in this preliminary test can not very well be taken into consideration in figuring the relative efficiency of the phosphate treatments.

The various phosphates to be tested were applied in the spring of 1897, together with liberal amounts of potash and nitrogen. In 1898, and again in 1914, all plots were treated with hydrated lime at the rate of 1 ton per acre, which was spread upon the plowed land and harrowed in. The annual application of fertilizer materials varied somewhat, the most important change being an increase of 50 per cent in the nitrate nitrogen and the actual potash in 1901. Since that date the annual rate of application per acre has been 91.2 pounds of nitrogen, 152 pounds of potash, and 96 pounds of phosphoric acid.

In order that the less soluble phosphates might have their full effect "a stock of organic matter was maintained in the soil by turning under heavy crops as follows: Winter rye in 1901, buckwheat in 1912, and rye in 1913, and by introducing grasses and clovers, 1905 to 1907, and turning under a heavy growth of grass in 1908."

Hopkins[3] considers that the supply of organic matter thus furnished was inadequate to meet the requirements of the crops and receive full benefit from the raw rock phosphate treatments.

The following table taken from Bulletin No. 153, of the Massachusetts station gives the increases in yield of various crops (over and above the check plots) obtained from plots treated with the different types of phosphates up to the close of 1914.

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[1] Mass. Agr. Expt. Sta., Bul. No. 162 (1915)

[2] Mass. Agr. Expt. Sta., 10th Ann. Rept., p. 17 (1898).

[3] Ill. Agr. Expt. Sta., Circ. No. 186, p. 13 (1916).

In reporting these results Brooks discarded the yields obtained during the first two years of the experiment on the assumption that the difference in the natural fertility of the plots would be less strongly marked after two years of fertilization. It might be said, however, that if the same plan had been followed in the earlier experiment where equal money values of the various phosphates were applied the average results would have been even more favorable to the less soluble phosphates than reported.

In comparing the crop yields in this later experiment each plot was compared with the check plots between which it lay and these checks were given a weight inversely proportional to their distance from the plot for which they served as a basis of comparison.

The validity of such a method of comparison is based on the assumption that the variations in the fertility of a field are fairly regular. Other investigators consider that a comparison of the average yield of all check plots with each treatment is a much fairer basis on which to compute differences in fertilizer values.

TABLE XXXIX.—*Average increase per acre in corps produced on plots treated with different classes of phosphates (1899–1914).*

Fertilizer.	Corn, 3 years, 1899, 1913, 1914.		Hay, 2 years, 1906, 1907.			Onions, 2 years, 1901, 1902.		Cabbage, 2 years, 1903, 1908.
	Grain.	Stover.	Hay.	Rowen.	Total.	Sound.	Scallions.	
	Bush.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Bush.*	*Bush.*	*Lbs.*
Natural mineral phosphates	−1.06	318.87	398.30	−131.00	267.30	−30.60	10.76	9,817.50
Basic slag and bone meals	8.03	905.50	615.55	97.33	712.88	143.60	−19.23	21,026.00
Dissolved phosphates	9.96	651.11	753.33	350.67	1,104.00	136.73	−12.56	18,758.60

Fertilizer.	Oat hay, 1 year, 1900.	Hungarian hay, 1 year, 1900.	Ensilage corn, 1 year, 1904.	Soy beans, 1 year, 1910.		Potatoes, 1 year, 1910.		Oat and alfalfa hay, 1 year, 1911.	Alfalfa hay, 1 year, 1911.
				Grain.	Straw.	Marketable.	Total.		
	Lbs.	*Lbs.*	*Lbs.*	*Bush.*	*Lbs.*	*Bush.*	*Bush.*	*Lbs.*	*Lbs.*
Natural mineral phosphates	231.70	166.70	−1,638.70	0.77	290.56	−10.70	−8.30	80.00	91.70
Basic slag and bone meals	1,324.40	−222.23	7,608.90	4.09	794.67	16.40	18.90	1,626.67	244.40
Dissolved phosphates	1,520.00	−253.30	7,361.30	3.87	776.00	26.90	29.50	1,560.00	73.30

It will be seen by dividing the phosphates into classes and taking the average yield of each class, as Brooks has done in his summary, the soluble phosphate plots on the whole surpassed all the other phosphates. Next in order came the so-called available phosphates, consisting of raw bone, steamed bone, and basic slag, and finally the lowest average yields were obtained from the plots treated with the natural phosphates of Arkansas, Florida, Tennessee, and South Carolina.

It seems questionable to the writers, however, if this method of grouping the various phosphates is altogether fair. By referring to Table XL it will be seen that the yields from the Florida soft phosphate plot were in many instances poor when the yields from the other raw-rock plots, particularly the South Carolina rock plot, were good. By grouping Florida soft phosphate with the South Carolina and Tennessee phosphates the average yield for raw rock is seriously affected.

Neither does the placing of dissolved bone meal, acid phosphate, and dissolved bone black in one group appear quite fair, since the first-mentioned material contains appreciable quantities of nitrogen, and in nearly every instance the yield of this plot exceeded the other soluble phosphate plots by a considerable margin.

In order that the reader may obtain a clearer idea of the value of each fertilizer treatment the writers have compiled the following table from the reports of this work as given from year to year during the entire period of the experiment. Full details of yields, however, are not given in the reports for the years 1898, 1899, 1900, 1905, 1908, 1909, 1911, and 1912.

TABLE XL.—*Results of 18 years' work,*[1] *in the growing of various crops on 13 plots of one-eighth acre each (1897–1914).*

Plot number.	Fertilizer.	Application per acre.	1897	1901	1902	1903	1904	1906	1907	1910	1913	1914
			Corn, yield per acre.	Onions, yield per acre.	Onions, yield per acre.	Cabbage, yield per acre.	Green corn, yield per acre.	Hay, yield per acre.	Hay, yield per acre.	Potatoes, yield per acre.	Corn yield, gain per acre.	Corn, yield per acre.
		Pounds.	*Bushels.*	*Bushels.*	*Bushels.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Bushels.*	*Bushels.*	*Bushels.*
1	None	....	58.5	279	196	13,400	41,000	6,600	8,400	286	....	79.6
2	Arkansas phosphate	376	56.5	222	102	20,920	40,720	7,520	8,800	289	−1.9	74.8
3	South Carolina rock phosphate	376	64.5	235	122	36,520	40,496	7,440	8,480	265	−2.2	80.5
4	Florida soft phosphate	364	72.5	151	52	25,680	28,240	7,600	8,480	235	−0.2	75.6
5	Basic slag	538	62.0	252	252	37,960	36,440	7,600	8,360	246	6.1	76.8
6	Tennessee phosphate	296	67.8	206	45	30,880	32,120	7,120	8,040	236	1.9	78.0
7	None	....	64.3	141	51	14,520	32,344	7,000	8,160	244	....	74.8
8	Dissolved bone black	522	61.8	210	174	39,912	30,080	6,960	9,200	248	3.5	84.2
9	Raw bone meal	404	67.3	252	301	44,240	45,800	7,120	9,240	259	7.3	85.6
10	Dissolved bone meal	432	63.3	213	389	42,080	41,840	7,520	9,160	264	14.3	77.3
11	Steamed bone meal	380	50.3	188	244	36,920	28,400	7,120	8,320	262	15.2	80.5
12	Acid phosphate	500	62.8	188	159	30,320	29,040	7,080	8,040	257	10.6	74.6
13	None	....	67.3	123	26	8,520	20,240	6,560	7,240	215	....	51.9

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[1] For the years 1898, 1899, 1900, 1905, 1908, 1909, 1911, and 1912 very incomplete data are given, and in no case are the results obtained on plots treated with raw rock phosphate reported.

By studying the detailed yields obtained during the 18 years of this experiment it will be seen that the method of computing fertilizer values used by Brooks, namely, comparison of the treatments with the nearest check plots, is distinctly favorable to the plots receiving soluble and so-called available phosphates, since these plots lie closer to the check giving lower yields. As far as the figures are complete in detail, the plots treated with South Carolina and Tennessee phosphate exceeded in yield those treated with acid phosphate in eight out of nine and six out of nine cases, respectively.

In view of the fact that the difference between the yields of the check plots in this experiment are in many instances much greater than the differences between the yields of the treated plots, the drawing of rigid conclusions concerning the value of the different types of phosphates hardly seems warranted. Neither of the two long-time field experiments conducted by the Massachusetts Station appear to warrant a definite conclusion concerning the relative merits of raw rock and acid phosphate. Under the conditions of the first experiment (where equal money values of the two forms of phosphoric acid were applied) the results indicate that raw rock was more effective than acid phosphate. In the second experiment (where phosphoric acid was applied in various forms at the same rate) the results may be interpreted as favorable or unfavorable to raw rock phosphate depending on the method employed in comparing the yields with those of the check plots.

MISSISSIPPI.

The first field work with raw rock phosphate conducted by the Mississippi station was described by Ferris[1] in 1906. Owing to the short duration (one year),[2] this experiment as well as six others[3] which were conducted for periods of from one to four years are not considered in detail in this bulletin.

In 1911 Ferris[4] reported the results of six years' work with fertilizers on cotton at the McNeill branch station, and early in 1912[5] gave the results obtained during six years of field work on corn and cotton.

The fields on which these experiments were conducted are described as nearly level and as uniform as possible. The soil, it is said, was typical of the pine lands in south Mississippi. The plots were one-twentieth acre in size, and the treatments on each crop were made in triplicate, the plots being so distributed as to reduce to a minimum the errors due to inequalities in the soil. Each plot received annually the same kind and quantity of fertilizer material.

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[1] Miss. Agr. Expt. Sta., Bul. No. 94 (1906).

[2] It is stated that this experiment was continued for four years but details are given for one year only.

[3] Miss. Agr. Expt. Sta., Buls. Nos. 110 (1908); 122 (1909); 155 (1911); 158 (1912); 161 (1913); 169 (1914).

[4] Miss. Agr. Expt. Sta., Bul. No. 155 (1911).

[5] Miss. Agr. Expt. Sta., Bul. No. 158 (1912).

In the case of the corn, cowpeas were grown as a catch crop in the field. It is not stated whether this latter crop was turned under or not. The results of these experiments are given in Tables XLI and XLII.

TABLE XLI.—*Yields of shucked ears of corn (per acre) obtained at McNeill branch station for 1907–1911, inclusive.*

Plot number.	Fertilizer.	Application per acre.	Yield per acre of shucked ears.				
			1906	1907	1908	1910	1911[1]
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1	Check	....	1,051	153	66	560	793
2	Cottonseed meal	100	1,699	740	446	860	1,406
3	Acid phosphate	100	2,037	1,380	846	840	1,880
4	Kainit	100	1,339	713	173	520	1,072
5	Cottonseed meal	100	1,886	1,200	1,073	1,220	1,792
	Acid phosphate	100					
7	Cottonseed meal	200	1,944	1,466	1,200	1,360	2,000
	Acid phosphate	100					
	Cottonseed meal	100	1,807	1,306	860	1,380	1,712
	Acid phosphate	200					
	Cottonseed meal	100	....	....	1,073	1,400	....
	Ground rock phosphate	100					
	Raw ground bone	100	2,094	1,526	....	....	....
12	Cottonseed meal	100	1,900	1,473	....	....	2,020
	Reverted phosphate	400					

[1] Fertilizer applications doubled in 1911.

NOTE.—Crop of 1909 was a failure.

TABLE XLII.—*Yields of seed cotton per acre obtained at McNeill branch station for 1907–1911, inclusive.*

Plot number.	Fertilizer.	Application per acre.	Yield per acre of seed cotton.					
			1906	1907	1908	1909	1910	1911[1]
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1	Check	....	480	220	110	153	20	30
2	Cottonseed meal	100	760	436	376	400	90	63
3	Acid phosphate	100	800	514	744	480	366	166
4	Kainit	100	620	300	274	186	34	8
5	Cottonseed meal	100	1,060	616	644	513	326	292
	Acid phosphate	100						
7	Cottonseed meal	200	1,040	756	684	620	306	370
	Acid phosphate	100						
8	Cottonseed meal	100	1,000	666	636	480	254	340
	Acid phosphate	200						
10	Cottonseed meal	100	840	510	....	520	....	220
	Ground rock phosphate	100						
11	Raw ground bone	100	....	....	720	....	....	....
12	Cottonseed meal	100	....	....	680	....	460	....
	Reverted phosphate	400	....	....				

[1] All applications of fertilizer doubled in 1911.

In these experiments the ground raw rock phosphate was applied in such relatively small amounts that little effect could be expected from its use. The yields of corn obtained from the raw rock cottonseed meal plot in 1908 and 1910, however, compare very favorably with the yields from the plots receiving mixtures of acid phosphate and cottonseed meal, and in every case the phosphate-cottonseed-meal mixtures gave substantially greater yields than the cottonseed meal alone.

The yields obtained in the cotton experiment, however, were more favorable to acid phosphate than to the raw rock, but the plots treated with the latter phosphate mixed with cottonseed meal gave a greater yield than those treated with cottonseed meal alone.

It may be said that while these experiments give a very limited amount of data on the fertilizer value of raw rock phosphate they indicate that even light applications of this material when supplemented with cottonseed meal may produce substantial increases in the yield of corn and cotton.

Of the nine field experiments with raw rock phosphate conducted by the Mississippi station only two were continued beyond four years. In these two the applications of the ground raw rock were so light that results can hardly be considered indicative of the value of this material. In practically all of the experiments, however, plots receiving raw rock phosphate, either alone or in combination with other fertilizer materials, have shown substantial increases over the check plots with which they were directly comparable.

MISSOURI.

The Missouri station advised the use of raw rock phosphate in 1905[1] and 1910,[2] but it was not until 1914 that any data obtained from field work was published by this station.

In an experiment described by Miller, Hutchison, Douglass, and Hudelson,[3] a study was made of the effect of various fertilizer treatments on both drained and undrained land in a four-year rotation of corn, oats, wheat, and cowpeas (with cowpeas grown and turned as a catch crop between the regular crops of the rotation).

The field selected for this experiment was a 10-acre tract of very level poorly drained prairie land lying one-half mile west of Vandalia. The soil was a dark-gray silt loam 7 to 9 inches in depth underlain by a silty clay. The field was divided into two equal parts and one half tiled and the other half left untiled. Each half was then divided into seven plots of seven-tenths acre each, running crosswise of the drained and undrained areas. The corresponding plots in each area were then treated as follows: Manure at the rate of 8 tons per acre, and raw rock phosphate at the rate of 600 pounds per acre every four years before corn, bone meal 150 pounds per acre, and potassium chloride 50 pounds per acre, twice during a rotation.

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[1] Mo. Agr. Expt. Sta., Circular of Information No. 22, p. 25 (1905).

[2] Mo. Agr. Expt. Sta., Bul. No. 84, p. 33 (1910); Bul. No. 86, p. 91 (1910).

[3] Mo. Agr. Expt. Sta., Bul. No. 118, 443–475 (1914).

Lime was also applied at the rate of 2,000 pounds per acre every four years. The first fertilizer applications were made in 1908, but in 1907 a crop of cowpeas was grown on the entire tract in order to compare the drained and undrained areas.

The results of five years' work with the fertilizer treatments mentioned above are given in Table XLIII.

TABLE XLIII.—*Yields of corn, oats, wheat, and cowpeas obtained on tiled and untiled land at Vandalia, Mo. (1908–1912).*

Fertilizer.	Application per acre.	Yield of various crops per acre.					
		Corn (1908).		Oats (1909).		Wheat (1910).	
		Drained.	Undrained.	Drained.	Undrained.	Drained.	Undrained.
Manure Rock phosphate Legume	*Tons.* [1] 8 *Pounds.* [1] 600	*Bushels.* 33.7	*Bushels.* 31.6	*Bushels.* 63.0	*Bushels.* 54.8	*Bushels.* 16.4	*Bushels.* 11.9
Manure Legume	8	34.4	26.5	58.5	57.4	12.4	10.2
Do.		31.6	26.3	56.9	52.2	9.0	5.1
Do. Bone meal	[2] 150	33.9	31.8	52.6	45.5	12.4	9.6
Legume Bone meal Potassium chloride	[2] 150 [2] 50	37.1	28.6	52.9	47.6	11.9	7.3
No fertilizer		32.4	25.5	47.9	38.8	8.5	4.5
Legume Bone meal Potassium chloride Lime	[2] 150 [2] 50 2,000	38.2	31.0	56.2	51.1	10.2	10.2

Fertilizer.	Application per acre.	Yield of various crops per acre.			
		Cowpea hay (1911).		Corn (1912).	
		Drained.	Undrained.	Drained.	Undrained.
Manure Rock phosphate Legume	*Tons.* [1] 8 *Pounds.* [1] 600	*Pounds.* 1,372	*Pounds.* 1,467	*Bushels.* 47.8	*Bushels.* 43.6
Manure Legume	8	1,227	1,199	44.9	41.0
Do.		2,018	1,171	40.6	33.2
Do. Bone meal	[2] 150	1,772	1,691	43.6	41.7
Legume Bone meal Potassium chloride	[2] 150 [2] 50	1,603	1,548	44.5	40.8
No fertilizer		1,492	1,152	42.9	40.8
Legume Bone meal Potassium chloride Lime	[2] 150 [2] 50 2,000	1,949	1,315	47.2	52.6

[1] Once every four years.

[2] Applied before corn and again before wheat.

Not only was no comparison made between raw rock phosphate and the acidulated phosphates in this experiment, but no strict comparison can be made between the plots treated with raw rock and those receiving bone meal, as in every case the two forms of phosphoric acid were used in conjunction with different fertilizers. The plots (both drained and undrained) which were treated with raw rock, manure, and a legume, however, showed substantial increases in yield over those receiving only manure and a legume (except the drained corn plot in 1908, and the undrained oat plot in 1909).

Miller, Hutchison, and Hudelson[1] described four other experiments in which an attempt was made to study the relative fertilizer merits of raw rock phosphate and steamed bone meal in four-year rotations. The experiments were conducted on four series of plots so that each crop was grown every year. The work was carried on at the following places: Jasper County, near Carthage; on the High Hill experiment field, Montgomery County; on the Hurdland experiment field, Knox County; and on the Laclede experiment field, Linn County.

The Jasper County experiment[2] was conducted for a period of only four years and is therefore not repeated in detail but the indications were that raw rock was quite effective when used in conjunction with manure, the average yield of these plots leading all others, with the exception of the average yield of wheat on the plots treated with lime, bone meal, and potash. In this experiment also there was no comparison made between acid phosphate and the less soluble forms of phosphoric acid.

The experiment field at High Hill,[3] Montgomery County, Mo., is located "on a slight ridge which slopes considerably to the west from the center of the field, with the east one-fourth sloping slightly to the east. In neither case is the fall sufficient to cause the land to wash badly." The field had been cropped to corn and oats for about twenty-five years, being in corn about two-thirds of the time. The soil is a gray silt loam grading into a dull gray silt below, which becomes heavier with depth, and interferes somewhat with the underdrainage. The soil is low in nitrogen, but fairly well supplied with phosphoric acid and potash. The plots were one-fifth acre each, and were laid out lengthwise across the slope. The experiment which was begun in 1907 was continued to 1913 (seven years) in a four-year rotation of corn, oats, wheat, and clover, but some of the crops were apparently not weighed. During the last year of the experiment, however, three out of four of the series of plots were planted to corn in order to determine the effect of the accumulation of fertility from previous treatments. The average results of seven years' work are given in Table XLIV.

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[1] Mo. Agr. Expt. Sta., Buls. Nos. 119, 126, 127, and 128.

[2] Mo. Agr. Expt. Sta., Bul. No. 119, pp. 3–17 (1914).

[3] Mo. Agr. Expt. Sta., Bul. No. 126, pp. 326–333 (1915).

TABLE XLIV.—*Average yields of corn, oats, wheat, cowpeas, barley, and clover hay in a 7-year experiment at High Hill, Mo. (1907–1913).*

Fertilizer.	Application per acre.	Corn, 8 crops.	Oats, 5 crops.	Wheat, 3 crops.	Cow-peas, 3 crops.	Bar-ley, 1 crop.	Clover, 1 crop.
		Bushels.	*Bushels.*	*Bushels.*	*Pounds.*	*Bushels.*	*Pounds.*
Legume		27.1	31.0	8.5	2,117	4.7	....
Do Bone meal	 150 pounds[1]	32.7	40.6	21.5	2,057	6.5	....
Legume Bone meal Lime	 150 pounds[1] 1 ton[2]	34.3	34.8	20.7	1,943	7.5	950
Legume Bone meal Lime Potassium chloride	 150 pounds[1] 1 ton[2] 50 pounds[1]	34.0	33.9	22.2	1,595	7.5	975
No treatment		22.5	23.9	9.0	1,267	3.7	....
Manure	8 tons[3]	33.0	27.3	12.6	1,842	3.7	....
Do Rock phosphate	do[3] 500 to 800 pounds[3]	34.7	30.0	17.2	2,071	4.7	....
Manure Rock phosphate Legume	8 tons[3] 500 to 800 pounds[3] 	36.4	33.9	20.5	1,775	8.2	....
Manure Rock phosphate Legume Lime	8 tons[3] 500 to 800 pounds[3] 2 tons[2]	38.7	37.6	20.6	1,717	9.4	1,275

[1] Application made every two years.
[2] Application made every six to eight years.
[3] Application made every four years.

As in the case of the other two Missouri experiments no strict comparison can be made between the plots treated with bone and those receiving raw rock phosphate, but the indications are that the reenforcement of manure with the latter material was quite effective.

The experiment field near Hurdland,[1] Knox County, Mo., "slopes slightly to the east and to the west from the middle driveway, giving only fair drainage." The soil is a dark-gray silt loam about 10 inches deep, which grades into heavier silt loam and finally into clay loam. According to the chemical analysis the soil was well supplied with potash and phosphoric acid, but low in nitrogen. The field had been in corn and oats for four years preceding the experiment, and previously had been in meadow. The field was laid out (like the three just described) in four tracts (A, B, C, and D) of eight plots each, the corresponding plots in each tract receiving the same fertilizer treatments. A four-year rotation of corn, oats, wheat, and clover (with cowpeas substituted when clover failed) was followed, each crop being grown on a different tract each year. The general plan of fertilizer treatment and the results of eight years' work (1907–1914) are given below in Table XLV.

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[1] Mo. Agr. Expt. Sta., Bul. No. 127, pp. 362–370 (1915).

TABLE XLV.—*Average yields of corn, oats, wheat, clover, cowpeas, and oat hay in an 8-year experiment at Hurdland, Mo. (1907–1914).*

Fertilizer.	Application per acre.	Corn, 8 crops.	Oats, 6 crops.	Wheat, 6 crops.	Clover, 3 crops.	Cow-peas, 1 crop.	Oat Hay, 1 crop.
		Bushels.	*Bushels.*	*Bushels.*	*Pounds.*	*Pounds.*	*Pounds.*
Legume		29.3	27.9	14.4	2,500	3,850	3,850
Do.		29.3	31.2	18.1	3,213	7,150	4,150
Bone meal	150 pounds[1]						
Legume		34.1	35.2	18.0	3,775	5,850	4,650
Bone meal	150 pounds[1]						
Lime	1 ton[2]						
Legume		37.8	34.3	17.1	4,116	6,100	4,050
Bone meal	150 pounds[1]						
Lime	1 ton[2]						
Potassium cholride	50 pounds[1]						
No treatment		33.1	26.9	13.7	2,741	4,200	2,200
Manure	8 tons[3]	41.6	31.6	17.7	3,341	3,525	3,225
Do.	8 tons[3]	40.4	32.0	17.2	3,241	5,450	3,700
Rock phosphate	1,000 pounds[3]						
Manure	8 tons[3]	35.2	35.7	18.5	3,300	4,150	3,500
Rock phosphate	1,000 pounds[3]						
Legume							

[1] Applications made every two years.
[2] Applications made every six years.
[3] Applications made every four years.

In the Hurdland experiment the addition of phosphate rock to manure seemed to have little effect, except in the case of cowpeas and oat hay, where the yields were considerably greater than on the plots receiving manure alone. Bone meal also seemed to be more effective on these same crops, but as in the case of the other experiments the data are such that no rigid conclusion can be drawn from a comparison of the results as to the relative value of the two forms of phosphoric acid.

The fourth experiment, similar in most respects to the three just described, is being conducted near Laclede, Linn County, Mo. The last published report[1] gives the results obtained after eight years' work in a four-year rotation of corn, oats, wheat, and clover (substituting cowpeas when the latter crop failed).

The field is located on gently rolling prairie land. The soil is the typical Shelby loam, which consists of a dark-brown loam to fine sandy loam, changing at a depth of about 10 inches to a light-brown or grayish-brown loam. The subsoil below 18 inches is a light-brown stiff sandy clay. According to the analysis the phosphoric acid and nitrogen content of this soil was rather low. The field was laid out in four tracts, each tract being subdivided into eight plots, as in the case of the three experiments just described. The fertilizer applications were the same as in the Hurdland experiment.

The results of eight years' work on the Laclede field are given in Table XLVI.

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[1] Mo. Agr. Expt. Sta., Bul. No. 128, pp. 388–394 (1915).

TABLE XLVI.—*Average yields of corn, oats, wheat, clover, and cowpeas in an 8-year experiment at Laclede, Mo. (1907–1914).*

Fertilizer.	Application per acre.	Corn, 6 crops.	Oats, 6 crops.	Wheat, 6 crops.	Clover, 2 crops.	Cowpeas, 4 crops.
		Bushels.	*Bushels.*	*Bushels.*	*Pounds.*	*Pounds.*
Legume		32.6	28.3	14.4	2,970	2,727
Do. Bone meal	 150 pounds[1]	39.1	35.3	16.9	4,540	3,377
Legume Bone meal Lime	 150 pounds[1] 1 ton[2]	43.3	37.3	16.2	4,650	3,604
Legume Bone meal Lime Potassium chloride	 150 pounds[1] 1 ton[2] 50 pounds[1]	46.1	40.3	19.9	4,940	3,582
No treatment		36.1	32.7	13.1	3,426	2,396
Manure	8 tons[3]	47.2	35.6	14.9	3,104	2,637
Do. Rock phosphate	8 tons[3] 500 pounds[4]	47.5	35.1	14.5	3,560	3,116
Manure Rock phosphate Legume	8 tons[3] 500 pounds[4] 	45.8	35.0	14.3	3,670	3,277

[1] Applications made every two years.
[2] Applications made every eight years.
[3] Applications made every four years.
[4] Applications made every four years, but in 1913, the rate was inceased to 1,000 pounds per acre.

The results obtained on the Laclede field are in a general way similar to those obtained at Hurdland, namely: The reenforcement of manure with phosphate rock apparently had little influence on the former's effectiveness, except in the case of the clover and cowpea crops. On the other hand, plots treated with bone meal in connection with a legume produced considerably better average yields of all crops than plots receiving the legume treatment only.

As in the case of the three previous experiments, however, no strict comparison between the bone and raw rock phosphate plots is possible, and since the yields of the various crops in the individual years are not given, the residual effect of the phosphate treatments can not be determined.

Four out of five field experiments with raw rock phosphate conducted by the Missouri Experiment Station cover a period of over five years. Two out of the four experiments reported in detail show increases resulting from the liberal use of raw rock phosphate in connection with organic matter. The other two show little or no benefit from applications of this material. No attempt was made in any of these experiments to compare the fertilizer value of raw rock and acid phosphate.

NEW JERSEY.

The first work of the New Jersey Experiment Station[1] on raw rock phosphate consisted of a series of cooperative experiments conducted by farmers in different sections of the State. Most of the experiments were conducted for one year only, and while several farmers continued their experiments for two years, the published reports show that different fields were employed the second year.

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[1] N. J. Agr. Expt. Sta., 6th, 7th, 8th Ann. Repts.

Three other series of field tests were published by the New Jersey Station in 1913,[1] but none was conducted for more than 2 years, so they do not warrant repetition.

In 1913, however, the New Jersey station carried on two pot experiments in cooperation with the basic slag committee of the Association of Official Agricultural Chemists.[2] The purpose of this investigation was to test the availability of the phosphoric acid in basic slag in comparison with other phosphates. Experiment No. 1 was conducted in pots holding 20 pounds of clean white sand practically free from any fertilizer elements. In experiment No. 2 pots were employed holding 18 pounds of gravelly loam, poor in nitrogen and organic matter, and containing about 0.07 to 0.08 per cent of P_2O_5 soluble in strong hydrochloric acid. Nitrogen, potash, iron, and sulphates were supplied to each pot. The phosphates were applied in such quantities as to furnish equal amounts of phosphoric acid, except the ground raw rock which supplied twice the quantity of phosphoric acid furnished by the other phosphates. Each treatment was run in duplicate, except the checks of which there were four. The crop grown was buckwheat which was harvested when the grain was beginning to ripen. The results of these experiments are given below in Table XLVII.

TABLE XLVII.—*Yields of buckwheat obtained in two pot experiments with pure sand and with gravelly loam treated as outlined below.*

Fertilizer.	Application per pot.	Experiment No. 1.		Experiment No. 2.	
		Weight of crop.	Increase over checks.	Weight of crop.	Increase over checks.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
No phosphate	....	[1]2.85	....	[1]24.10	....
Acid phosphate	5.82	16.10	13.50	30.35	6.77
Sodium phosphate	4.97	3.30	.70	29.65	6.07
Basic slag A	5.67	14.15	11.55	31.15	7.57
Basic slag B	5.45	16.50	13.90	35.20	11.62
Basic slag C	7.79	14.95	12.35	27.80	4.22
Basic slag D	6.54	15.35	12.75	33.35	9.77
Blue rock phosphate	7.05	9.85	7.25	24.40	.82
Double superphosphate	2.24	17.75	15.15	31.70	8.12
No phosphate	....	[1]2.35	....	[1]23.05	....

[1] Average of two pots.

In experiment No. 1, where the crop was grown in pots containing pure sand to which the same amounts of sodium nitrate, potassium sulphate, etc., were added, the water soluble phosphates produced the largest yields, closely followed, however, (and in one case equaled) by the basic-slag pots. The raw rock phosphate pots produced an appreciable increase in yield over the no-phosphate pots, but far less than any of the other treated pots except those receiving sodium phosphate. This latter compound, it is said, seemed to have a toxic effect.

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[1] N. J. Agr. Expt. Sta., 34th Ann. Rept. (1914); 35th Ann. Rept. (1915).

[2] N. J. Agr. Expt. Sta., 34th Ann. Rept., 481–484 (1914).

In experiment No. 2, where a soil was employed, the raw-rock pots gave little or no increase over the checks, while those treated with basic slag produced in most instances greater yields than the acid phosphate pots.

The data obtained in these pot experiments, however, are of such limited value (owing to their short duration, and also to the fact that only a single crop was tested) that the writers have hesitated to present them, but as far as they go they indicate that liberal applications of phosphoric acid in the form of acid phosphate and basic slag were superior to twice the quantity in the form of raw rock phosphate.

NEW YORK.

The first three experiments[1] conducted by the New York Experiment Station with raw rock phosphate as a fertilizer were of such short duration and the data presented are so limited that they are not considered in detail in this bulletin.

In some pot or greenhouse experiments conducted by the Geneva station from 1896 to 1900 sufficient data are given to warrant a repetition of the figures and a discussion of some of the details.

The soils in which the plants were grown in the several experiments were as follows:

In 1896–97 a natural sandy pine land soil, supposedly poor, was used (110 pounds per box). In 1898–99 quartz sand containing from 99.5 to 99.7 per cent SiO_2 was employed (46 pounds per box with 12 pounds of coarse material for drainage). In 1899–1900 for some crops the same sand which had been used during the previous year after removing roots and organic matter and for some crops an equal quantity (46 pounds) of fresh sand.

Adequate quantities of readily available nitrogen and potash carriers were added in each case and the same amount of phosphoric acid was added to each can or box in the forms given in the table. The effect of these phosphates on the yield of several orders of plants was studied by running each treatment in duplicate.

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[1] N. Y. Agr. Expt. Sta., 7th Ann. Rept., pp. 356–363 (1889) ; 8th Ann. Rept., pp. 256–258 (1890) ; Cornell Buls. Nos. 143 (1898) ; 166 (1899) ; 182 (1900) ; 201 (1902).

TABLE XLVIII.—*Yields of certain crops obtained in pots containing 110 pounds of poor sandy soil treated with available nitrogen and potash, etc., and various phosphates.*

Fertilizer.	Application of P_2O_5 per pot.	Yield (1896–97).					
		Oats.	Rye.	Beans.	Vetch.	Cabbage.	Rape.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Acid phosphate	4	93.5	226.8	22.4	111.2	57.5	61.4
Florida rock (floats)	4	85.7	205.5	13.8	85.7	53.0	55.2
Thomas slag	4	115.1	212.0	14.8	98.8	54.8	60.7
Redonda phosphate	4	93.0	215.0	16.9	87.6	53.2	59.5
No phosphate		90.7	194.0	13.3	75.3	53.0	45.8
No fertilizer (of any kind)		7.3	39.5	11.1	75.6	13.0	11.4

TABLE XLIX.—*Yields of certain crops obtained in boxes containing 46 pounds of pure sand (99.6 per cent SiO_2), treated with available nitrogen and potash, etc., and with various phosphates.*

Form of phosphate.	Application per box.	Yield of crops (1898–99).							
		Barley.	Millet.	Oats.	Clover.	Vetch.	Tomatoes.	Cabbage.	Rape.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Acid phosphate	3	189.6	29.2	210.2	93.8	88.5	58.7	82.2	91.4
Florida rock (floats)	3	9.3	1.1	9.1	2.6	31.8	1.8	64.5	72.3
Thomas slag	3	181.4	8.8	198.9	74.0	67.5	48.4	80.0	98.4
Redonda phosphate	3	150.1	14.4	170.2	37.1	61.9	57.2	65.4	74.9
No phosphate		7.9	1.2	6.8	2.4	2.7		.5	.8
No fertilizer (of any kind)		10.9	1.1	10.0	4.5	2.7		3.6	3.4

TABLE L.—*Yield of certain crops obtained in boxes containing 46 pounds pure sand (99.6 per cent SiO_2), treated with available potash and nitrogen, etc., and with various phosphates.*

Form of phosphate.	Application per box.	Yield of crops (1899–1900).					
		Barley.	Peas.	Vetch.	Tomatoes.	Cabbage.[1]	Rape.[1]
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Acid phosphate	1.5	34.2	19.8	9.6	11.5	38.3	29.3
Florida rock (floats)	1.5	8.8	12.5	4.8		46.0	28.1
Thomas slag	1.5	21.1	15.9	8.1	8.4	45.8	10.9
Redonda phosphate	1.5	18.6	13.8	8.3	7.6	20.0	17.1
No phosphate		6.8	7.7	2.6			
No fertilizer (of any kind)		4.9	3.7	2.0			

[1] Cabbage and rape were grown on the sand used the previous year to which 4 grams of P_2O_5 were added in the various forms given above.

A study of Tables XLVIII, XLIX, and L will show that the cruciferous plants (cabbage and rape) seemed to utilize the phosphoric acid of raw rock phosphate almost as well as they did the more soluble forms, but that nearly all the other plants gave greater yields where they were treated with acid phosphate. In Table LXVIII, where a sandy soil was used, the difference between the soluble and insoluble phosphate pots was not so marked, owing in part no doubt to the fact that the soil originally contained phosphates. In the other two experiments, however, the sand used contained no phosphate, except that added and it is rather surprising that such additions of raw phosphate as were made, applications supplying from 0.008 to 0.014 per cent of phosphoric acid, which is less than that contained in a soil abnormally low in this element, should have proved so effective, particularly in the absence of organic matter. In order to test the influence of fine grinding on the availability of raw rock phosphate and bones two pot experiments were conducted under the direction of W. H. Jordon[1] of the Geneva station. In one of these experiments (1899–1900) 58 pounds of pure quartz sand per pot were used to which no organic matter had been added, and in the other (1903–4) 43 pounds of sand per pot were employed to which about 3 per cent of dried ground sphagnum moss was added. In both experiments all the pots except the blanks were supplied with the necessary fertilizer elements, the phosphoric acid, however, being applied in the forms of acid phosphate, bone, and ground raw rock of various degrees of fineness.

In the first experiment three successive crops of rape were grown without renewing the phosphate treatments for the second and third crops, but the barley was grown in a separate set of pots. In the second experiment the crops grown were peas, barley, and rape, but each in separate sets of pots. The plants in every instance were allowed to attain the fullest development possible under the conditions. They were then harvested and weighed. The results obtained are given in part in Table LI which is compiled from two tables taken from Bulletin No. 358, of the Geneva station.

TABLE LI.—*Box experiment to test the effect of raw rock phosphate of various degrees of fineness on different crops; boxes contained 46 pounds each of pure quartz sand supplied with all fertilizer elements.*

Treatment.	Application of P_2O_5 per box.[2]	1899–1900				1903–4		
		Rape, first crop.	Rape, second crop.	Rape, third crop.	Barley.	Peas.	Barley.	Rape.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blanks	....	....	....	....	....	8.4	12.2	....
Acid phosphate	3	72.3	49.3	26.2	66.4	69.9	166.7	48.0
Florida rock:								
60-mesh	3	47.5	30.9	25.0	7.6	64.1	140.0	54.5
80-mesh	3	36.5	30.1	27.6	9.0	63.1	165.7	58.2
100-mesh	3	37.6	28.5	29.3	6.8	62.8	176.3	56.3
Bolting cloth	3	46.3	28.4	29.4	7.8	60.3	164.4	58.7
Fine	3	45.2	34.0	31.3	7.3	67.5	172.9	58.8
Floats	3	52.8	35.6	32.4	11.1	68.0	162.7	57.7
Bone meal:								
60-mesh	3	54.8	36.9	32.7	9.8	59.8	160.0	46.5
80-mesh	3	53.0	35.9	33.0	7.3	60.4	168.7	46.8
100-mesh	3	54.5	40.1	32.7	6.9	62.7	175.3	40.7
Bolting cloth	3	60.9	35.1	36.0	6.9	61.6	164.6	44.8
Finest	3	49.2	39.4	26.7	9.5	59.6	177.0	48.6

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[1] N. Y. Agr. Expt. Sta. (Geneva), Bul. No. 358 (1913).

[2] In the experiments conducted in 1903–4 only 1.5 grams of P_2O_5 per pot were used, but organic matter was added in the form of sphagnum moss.

It is evident from the figures given in Table LI that the more finely raw rock phosphate is ground the more effective it becomes. The floats in almost every instance produced appreciably greater yields than the coarser phosphatic material. The same is true, though to a less extent, of bone meal.

In the first experiment (1899–1900) where no organic matter was applied, the pots treated with acid phosphate showed greater yields than those treated with the less soluble phosphates, but in the second experiment where organic matter was added the very finely ground raw rock and floats gave as good and better yields than the acid phosphate, although it was supplied in quantities far less than phosphates occur in most soils.

One other pot experiment to test the fertilizer value of several relatively insoluble phosphates on barley was conducted by the Geneva[1] station in 1912.

The same artificial soil employed in the previous experiments was used in this test, but the quantity of phosphoric acid added to each pot in the various forms was from two to four times as great. Adequate amounts of potash and nitrogen were added to each pot, but no organic matter was employed. Each treatment was run in duplicate.

The average results of this experiment are given in Table LII.

TABLE LII.—*Yields of barley obtained in a pot experiment*[1] *(58.9 pounds of soil) with various phosphatic fertilizers; potash and nitrogen supplied to all pots.*

Form of phosphates.	Amount of P_2O_5 added per pot.	Yield of barley per pot.
	Grams.	*Grams.*
Monocalcium phosphate	5.82	71.0
Iron ore waste	5.82	44.2
Basic slag	5.82	68.7
Ground Tennessee rock	5.82	55.7
Bone	5.82	74.7
Blanks	....	38.2

The monocalcium phosphate, bone, and basic-slag treatments all gave yields of barley greater than the ground Tennessee rock, but apparently this crop was able to utilize to a certain extent the phosphoric acid of this latter material.

In view of the fact that barley in previous experiments has not responded readily to the less soluble forms of phosphoric acid when they were present in small quantities, the results of this experiment are not surprising, for while greater amounts of phosphoric acid were added than in the previous experiments with the artificial soil, the total quantity present in each pot was still considerably below that present in a soil of low phosphate content.

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[1] N. Y. Agr. Expt. Sta. (Geneva). Fertilizer Value of An Iron Ore Waste. Bul. No. 358, pp. 252–253 (1913).

While only one field experiment (of two years' duration) with raw rock phosphate has been reported by the New York stations, the six pot experiments warranting consideration in detail indicate that this material increases the yield of a number of crops even when applied in very small quantities. The data also seem to show that the presence of organic matter renders the raw phosphate more effective. A comparison of the relative merits of the different phosphates used in these experiments, however, is hardly admissible.

NORTH CAROLINA.

The work with raw rock phosphate reported by this State consists of three field experiments[1] conducted for periods of one to three years. Owing to the short duration of these experiments and also to the fact that the data presented in two of them are very limited, one is hardly justified in considering the results even indicative of the relative merits of the phosphates used.

OHIO.

Probably the most valuable experiment with raw rock phosphate yet reported is one undertaken by the Ohio station in 1897.[2] Not only has this experiment been conducted over a considerable period of time (18 years), but the raw rock phosphate has been applied in a manner generally thought to render it most effective under soil conditions. Moreover, a direct comparison is made between this form and the more soluble form of phosphoric acid in superphosphate.

The field selected for this experiment was rather below the average in fertility, but no data are available showing the relative natural productivity of the treated plots. The yields of most of the check plots, however, with the exception of No. 1, section A, No. 7, section B, and No. 1, section C, have agreed fairly well throughout the experiment, indicating that the field is comparatively uniform. The soil is a sandy clay of glacial drift origin. In 1892 it grew a crop of oats and in 1893 it was plotted, drained, and sown to wheat. Clover and timothy were grown in 1895 and 1896.

Up to the time of the experiment herein described, no manure whatever had been applied to the field since it came into the possession of the State.

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[1] N. C. State Board of Agr., Bul. No. 128 (1907); N. C. Dept. Agr., Bul. No. 151, pp. 31–34 (1911); N. C. Agr. Expt. Sta., Bul. No. 227 (1914).

[2] Ohio Agr. Expt. Sta., Buls. Nos. 110, 134, 183, 184, 246, 305; Circulars Nos. 54, 83, 92, 104, 114, 120, 131, 144.

In 1897 the field was divided into three tracts containing 20 plots each, and a three-crop rotation of corn, wheat, and clover begun, so that each crop was grown every year and each tract received every third year the fertilizer treatments outlined below.

A quantity of manure from the stable, where it had collected under the feet of animals kept continually in their stalls, was taken and divided into five equal parts, four of which were treated with various reenforcing materials at the rate of 40 pounds to the ton of manure. The fifth portion was left untreated. Equal or equivalent amounts of manure from the open barnyard were similarly treated with the same materials. After standing for some time the manure thus treated was spread upon clover sod at the rate of 8 tons to the acre, and plowed under for corn which was followed by wheat and clover. During the first three seasons soy beans were grown and plowed under, since clover was a failure. The arrangement of the plots is shown in the following diagram taken from the Ohio station reports; and the average yields per acre for 18 crops[1] and the increases in yield due to the various applications are given in Tables LIII and LIV.

Arrangement of plots and plan of fertilizing in experiments with manure; plots one-sixteenth acre each.

11. Nothing.	Section A.	Nothing.	1.
12. Yard manure, gypsum.		Yard manure, floats.	2.
13. Stall manure, gypsum.		Stall manure, floats.	3.
14. Nothing.		Nothing.	4.
15. Yard manure, untreated.		Yard manure, acid phosphate.	5.
16. Stall manure, untreated.		Stall manure, acid phosphate.	6.
17. Nothing.		Nothing.	7.
18. Chemical fertilizer.		Yard manure, kainit.	8.
19. Chemical fertilizer.		Stall manure, kainit.	9.
20. Nothing.		Nothing.	10.
11. Nothing.	Section B.	Nothing.	1.
12. Yard manure, gypsum.		Yard manure, floats.	2.
13. Stall manure, gypsum.		Stall manure, floats.	3.
14. Nothing.		Nothing.	4.
15. Yard manure, untreated.		Yard manure, acid phosphate.	5.
16. Stall manure, untreated.		Stall manure, acid phosphate.	6.
17. Nothing.		Nothing.	7.
18. Chemical fertilizer.		Yard manure, kainit.	8.
19. Chemical fertilizer.		Stall manure, kainit.	9.
20. Nothing.		Nothing.	10.
11. Nothing.	Section C.	Nothing.	1.
12. Yard manure, gypsum.		Yard manure, floats.	2.
13. Stall manure, gypsum.		Stall manure, floats.	3.
14. Nothing.		Nothing.	4.
15. Yard manure, untreated.		Yard manure, acid phosphate.	5.
16. Stall manure, untreated.		Stall manure, acid phosphate.	6.
17. Nothing.		Nothing.	7.
18. Chemical fertilizer.		Yard manure, kainit.	8.
19. Chemical fertilizer.		Stall manure, kainit.	9.
20. Nothing.		Nothing.	10.

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[1] This applies to all plots, except the commercial fertilizer plots the results of which are the averages of 16 years.

TABLE LIII.—*Yields per acre of corn, wheat, and hay—average for the 18-year period, 1897–1915.*

Plot number.	Treatment.	Corn.		Wheat.		Hay.
		Grain.	Stover.	Grain.	Straw.	
		Bushels.	*Pounds.*	*Bushels.*	*Pounds.*	*Pounds.*
1	None	40.62	2,365	13.28	1,543	3,020
2	Yard manure and raw phosphate	63.40	3,464	24.94	2,674	4,357
3	Stall manure and raw phosphate	66.75	3,677	26.46	2,869	4,765
4	None	32.38	2,050	11.75	1,370	2,299
5	Yard manure and acid phosphate	63.69	3,372	26.57	2,907	4,260
6	Stall manure and acid phosphate	67.04	3,578	27.06	3,031	4,851
7	None	31.16	1,982	10.90	1,319	2,314
8	Yard manure and kainit	56.67	3,232	21.52	2,423	3,547
9	Stall manure and kainit	61.54	3,475	23.13	2,691	4,238
10	None	34.14	2,049	11.14	1,364	2,488
11	.....do	38.97	2,375	14.40	1,732	3,251
12	Yard manure and gypsum	60.62	3,400	24.39	2,712	3,885
13	Stall manure and gypsum	61.48	3,498	24.31	2,695	3,909
14	None	31.77	2,037	11.29	1,334	2,354
15	Yard manure, untreated	52.85	2,921	20.72	2,296	3,337
16	Stall manure, untreated	59.37	3,271	22.03	2,494	4,000
17	None	37.94	2,331	11.59	1,409	2,694
18	Chemical fertilizer	47.78	2,690	16.16	1,841	3,163
19	.....do	45.20	2,494	15.42	1,885	3,255
20	None	33.88	2,028	10.72	1,382	2,679
	Average from manure and raw phosphate.	65.07	3,570	25.70	2,771	4,561
	Average from manure and acid phosphate.	65.36	3,475	26.81	2,969	4,555
	Average from manure untreated	56.11	3,096	21.37	2,395	3,668
	Average unmanured yields	34.77	2,153	11.76	1,395	2,536

TABLE LIV.—*Barnyard manure on crops grown in three-year rotation. Average annual increase per acre for entire period of experiment figured first according to Thorne, by comparing treated plots with the two nearest check plots, and second by comparing treated plots with average of all check plots.*

Plot number.	Treatment.	Average annual increase according to Thorne.				
		Corn, 18 crops.		Wheat, 18 crops.		Clover hay, 15 crops.
		Grain.	Stover.	Grain.	Straw.	
		Bushels.	*Pounds.*	*Bushels.*	*Pounds.*	*Pounds.*
2	Yard manure and floats	25.53	1,204	12.17	1,189	1,578
3	Stall manure and floats	30.95	1,522	14.20	1,492	2,225
5	Yard manure and acid phosphate	31.72	1,344	15.09	1,554	1,956
6	Stall manure and acid phosphate	35.48	1,572	15.68	1,693	2,542
8	Yard manure and kainit	24.11	1,237	10.54	1,089	1,176
9	Stall manure and kainit	28.40	1,449	12.07	1,343	1,807
12	Yard manure and gypsum	23.83	1,171	11.02	1,113	931
13	Stall manure and gypsum	27.31	1,348	11.97	1,229	1,255
15	Yard manure, untreated	19.03	815	9.33	939	870
16	Stall manure, untreated	23.48	1,015	10.46	1,110	1,419
18	Chemical fertilizer[1]	10.74	475	4.22	394	482
19	.....do[2]	10.48	400	4.26	472	635

[1] Acid phosphate, 80 pounds; muriate of potash, 80 pounds; nitrate of soda, 160 pounds.

[2] Acid phosphate, 80 pounds; muriate of potash, 10 pounds; tankage (7–30), 100 pounds.

TABLE LIV.—*Barnyard manure on crops grown in three-year rotation, etc.*—Con.

Plot number.	Treatment.	Average annual increase obtained by comparison with average of all check plots.				
		Corn, 18 crops.		Wheat, 18 crops.		Clover hay, 15 crops.
		Grain.	Stover.	Grain.	Straw.	
		Bushels.	*Pounds.*	*Bushels.*	*Pounds.*	*Pounds.*
2	Yard manure and floats	27.54	1,312	13.06	1,242	1,718
3	Stall manure and floats	30.88	1,525	14.58	1,437	2,138
5	Yard manure and acid phosphate	27.83	1,220	14.69	1,475	1,621
6	Stall manure and acid phosphate	31.18	1,426	15.18	1,599	2,214
8	Yard manure and kainit	20.81	1,080	9.64	991	910
9	Stall manure and kainit	25.68	1,323	11.25	1,259	1,601
12	Yard manure and gypsum	24.76	1,248	12.51	1,280	1,278
13	Stall manure and gypsum	25.52	1,346	12.43	1,263	1,272
15	Yard manure, untreated	16.99	769	6.40	864	700
16	Stall manure, untreated	23.51	1,119	10.78	1,062	1,363
18	Chemical fertilizer[1]	12.24	548	3.88	392	585
19	.....do[2]	10.58	359	3.73	471	722

[1] Acid phosphate, 80 pounds; muriate of potash, 80 pounds; nitrate of soda, 160 pounds.
[2] Acid phosphate, 80 pounds; muriate of potash, 10 pounds; tankage (7-30), 100 pounds.

A study of Table LIII will show that applications of stall manure produced greater yields than yard manure, and that the mixing of floats with the stall manure rendered them considerably more effective than where they were mixed with yard manure.

Phosphates proved more desirable as reenforcers of manure than either kainit or gypsum. Where the two forms, raw rock and acid phosphate, were thus used at the rate of 320 pounds per acre every three years, the plots treated with the latter gave slightly greater yields. Moreover, in spite of the fact that a greater quantity of phosphoric acid had actually been added to the plots in the form of raw rock phosphate, and the conditions were favorable for rendering this accumulated phosphoric acid available, the acid phosphate treatments appeared to be slightly more effective even after 17 years.

On the other hand, Thorne in comparing the various fertilizer treatments with the check plots assumes that any change in fertility of the soil of the various plots in the experiment field is gradual and, therefore, the treated plot under consideration should be compared with the nearest check plots rather than with the average of all the checks.

Hopkins[1] takes issue with Thorne on this point, saying "that the change in the direction of such a curve is just as likely to occur on any other plot as on the plots that happen to be numbered 1, 3, 4, 7, etc." The latter writer also points out that several of the check plots in this experiment are apparently abnormal, and Thorne's system of comparison is unfavorable if not unfair to the raw rock plots.

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[1] Soil Fertility and Permanent Agriculture, p. 250.

In Table LIV the average annual increase per acre for each treatment is figured both by the Ohio system and also by comparing the treated plots with the average of all the check plots. These two systems of comparison lead to very different conclusions. By the Ohio method acid phosphate appears to much greater advantage than raw rock, even though the latter is considerably less costly. By the second method of comparison the applications of raw rock phosphate show increases in yield practically as good and in some cases better than those obtained from equal applications of acid phosphate.

Another point worthy of serious consideration in this experiment is that the applications of raw rock were not very liberal for such a relatively insoluble material, the effectiveness of which depends largely on its thorough distribution in the soil. Such distribution must be brought about principally by heavy applications. According to analysis, the soil on which this experiment was conducted was relatively low in phosphoric acid (0.08 per cent P_2O_5) yet even had none of the phosphate rock added during the 17 years of the experiment been removed by crops or lost in other ways, the total quantity of phosphoric acid present in the upper 9 inches of the soil would only have been increased to 0.1 per cent. The crops grown were such as would remove an amount of phosphoric acid equal approximately to one-half of that added in the form of raw rock so at the expiration of 17 years the soil should have contained about 0.01 per cent more phosphate than at the beginning of the experiment, an amount which in spite of thorough tillage and frequent cultivation was probably not uniformly distributed in the soil. An experiment similar to the one just described, except using heavier applications of phosphate rock would be interesting, and yield valuable data on this subject.

Another experiment with raw rock phosphate in which a three year rotation of corn, oats, and clover was followed, was begun at Wooster in 1905.[1] The following description of the field employed, and the history of the experiment which is known as the Lime and Floats Test, is taken directly from Circular No. 144 of the Ohio Station:

> The land had been under the regular rotative cropping of the farm since its occupation by the Station, and for a considerable period before, and was in good condition—12 tons of manure per acre had been plowed under for corn in 1904. Three sections of 26 plots each are included in the test, the plots containing one-twentieth acre each.
>
> For the crops of 1905, section A (north end) was manured at the rate of 6 tons per acre only (because of the recent application above mentioned), limed, fertilized, and planted to corn. Section B was sown to soy beans instead of clover, the beans to be followed by rye in the fall and corn in 1906. Section C

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[1] Ohio Agr. Expt. Sta., Circular No. 144, pp. 92–93 (1914).

(south end) was limed and fertilized without manure, and sown to oats and clover. Thenceforth the manure, lime, and fertilizers have all been applied to the corn crops, the manure being plowed under and the lime and fertilizers applied to the surface. The oats and clover receive no treatment. The clover seeding failed in 1906, 1908, and 1909, and soy beans were grown instead and harvested as hay.

The plan of treatment, average yields per acre, for nine years, and the increase per acre from the various treatments figured according to the Ohio method and also by comparing each treatment with the average of all the untreated plots are given in Table LV.

The results obtained in 1914 and 1915 have been reported by Thorne in Bulletin No. 305 of the Ohio station, but no yields are given except those of the plots receiving acid phosphate and raw rock. These last two years' results therefore are not included in the averages given in Table LV.

TABLE LV.—*Average yields and increase per acre of crops grown in 3-year rotation under treatment with manure, lime, and floats.*

[Plots one-twentieth acre each.]

Plot number.	Treatment (lime, manure, etc., per acre applied to corn only).	Average yield per acre, 1905–1913, inclusive.					Average increase in yield per acre.									
		Corn, 9 years.		Oats, 9 years.		Clover-cowpea hay, 8 years.	According to Thorne.					Obtained by comparison with average of all check plots.				
							Corn.		Oats.		Hay, 8 years.	Corn.		Oats.		Hay, 8 years.
		Grain.	Stover.	Grain.	Straw.		Grain.	Stover.	Grain.	Straw.		Grain.	Stover.	Grain.	Straw.	
		Bush.	*Lbs.*	*Bush.*	*Lbs.*	*Lbs.*	*Bush.*	*Lbs.*	*Bush.*	*Lbs.*	*Lbs.*	*Bush.*	*Lbs.*	*Bush.*	*Lbs.*	*Lbs.*
1	None	52.57	2,804	43.16	2,267	4,201										
2	Caustic lime, 500 pounds; manure, 8 tons	70.42	3,500	50.98	2,502	5,313	17.57	670	6.66	294	1,030	18.92	741	6.04	541	1,239
3	Caustic lime, 1,000 pounds; manure, 8 tons	72.62	3,584	51.20	2,477	5,470	19.48	728	5.72	329	1,105	21.12	825	6.26	516	1,396
4	None	53.42	2,882	46.64	2,089	4,447										
5	Caustic lime, 2,000 pounds; manure, 8 tons	75.95	3,833	52.70	2,536	5,933	21.80	930	5.96	441	1,470	24.45	1,074	7.76	575	1,859
6	Ground limestone, 1,780 pounds; manure, 8 tons	75.14	3,649	53.08	2,526	5,634	20.26	724	6.24	426	1,156	23.64	890	8.14	565	1,560
7	None	55.61	2,974	46.93	2,104	4,492										
8	Air slaked lime, 1,780 pounds; manure, 8 tons	74.74	3,809	53.75	2,628	5,766	19.84	902	7.43	551	1,393	23.24	1,050	8.81	667	1,692
9	Hydrated lime, 1,320 pounds; manure, 8 tons	71.70	3,722	53.53	2,617	5,520	17.52	856	7.84	567	1,265	20.20	963	8.59	656	1,446
10	None	53.46	2,827	45.08	2,022	4,135										
11	Gypsum, 1,000 pounds; manure, 8 tons	67.28	3,387	51.86	2,268	4,605	15.10	611	6.87	295	566	15.78	628	6.92	307	531
12	Floats, 1,000 pounds; manure, 8 tons	67.43	3,387	53.42	2,383	4,768	16.54	661	8.54	459	827	15.93	628	8.48	422	694
13	None	49.60	2,676	44.78	1,876	3,844										
14	Caustic lime, 1,000 pounds	57.33	3,149	47.53	2,079	4,580	7.74	461	2.63	218	771	5.83	390	2.59	118	506
15	Ground limestone, 1,780 pounds	54.84	2,820	45.35	1,876	4,362	5.26	121	.32	28	588	3.34	61	.41	00	288
16	None	49.58	2,711	45.14	1,833	3,738										
17	Caustic lime, 1,000 pounds; acid phosphate, 320 pounds; muriate potash, 40 pounds	70.45	3,558	50.55	2,061	5,084	20.13	829	5.40	202	1,264	18.95	799	5.61	100	1,010
18	Caustic lime, 1,000 pounds; floats, 320 pounds; muriate potash, 40 pounds	66.43	3,438	48.35	1,972	4,991	15.36	691	3.18	87	1,091	14.93	679	3.41	11	917
19	None	51.81	2,764	45.19	1,911	3,981										
20	Acid phosphate, 320 pounds	60.18	3,056	46.16	1,912	4,277	8.55	315	1.19	37	271	8.68	297	1.22	00	202
21	Acid phosphate, 320 pounds; muriate of potash, 40 pounds	66.22	3,327	47.88	2,014	4,443	14.78	611	3.14	176	413	14.72	568	2.94	53	369
22	None	51.27	2,691	44.52	1,802	4,055										
23	Floats, 320 pounds	53.58	2,742	45.17	1,842	4,060	4.06	104	1.16	57	104	2.08	00	.23	00	00
24	Floats, 320 pounds; muriate of potash, 40 pounds	56.63	3,016	44.80	1,808	3,912	8.87	431	1.31	42	54	5.13	257	00	00	00

25	None	46.01	2,531	42.98	1,749	3,759	....	....	....	....	....	....	....	....	....	....
26	Manure, 8 tons since 1909[1]	55.97	3,049	46.56	1,951	4,475	17.34	816	3.58	202	715	4.47	290	1.62	00	401
	Average unfertilized yield	51.50	2,759	44.94	1,961	4,074	....	....	....	....	....	....	....	....	....	....

[1] Previously, floats, 320 pounds; muriate potash, 40 pounds; dried blood, 100 pounds.

Note.—The lime or gypsum or floats and manure are not mixed together. The manure is plowed under and the lime or other materials applied to the surface.

An inspection of Table LV will show that here again very different conclusions may be drawn from the experimental data, depending on the method used in comparing the checks with the various fertilized plots.

According to the Ohio method of comparison raw rock phosphate when applied alone at the rate of 320 pounds per acre gave some slight increases in yield, though not as great as the same quantity of acid phosphate. By the second method of comparison, however, practically no increase was obtained from such small applications of raw rock.

Again, by the Ohio method of calculation, manured plots on which raw rock phosphate was applied at the rate of 1,000 pounds per acre as a top dressing gave an average increase in yield less than that obtained from plots receiving manure alone. According to the second method of comparison, however, the plots receiving such heavy applications of phosphate rock produced considerably greater yields than those receiving manure alone. There were no plots in this experiment on which acid phosphate and manure were used in conjunction.

Another experiment with raw rock phosphate, using a rotation of beets, oats, and clover, was begun by the Paulding County Experiment Station in 1911,[1] but since the data so far published on this experiment cover only three years or one complete rotation it is too early to draw any conclusions therefrom.

In what are known as the "Strongville experiments"[2] the Ohio station has made a comparison of the relative effect of lime and floats in a five-year rotation of corn, oats, wheat, clover, and timothy.

The field used in this experiment is nearly level east and west, but slopes gently to the north. It was divided into four sections (A, B, C, and D) containing 40 plots of one-tenth acre each. The soil of the field is a heavy white clay naturally low in phosphoric acid, and had been employed in a fertilizer experiment under the same system of rotation for 12 years. After the introduction of the lime and floats the applications of the other fertilizer materials were continued as before, but each plot was divided into two parts, on one of which floats were applied and on the other ground limestone. The dressings have been 2 tons of limestone per acre on the south half of each entire section, and 1 ton of floats per acre on the north half, the applications being made on the corn crop only. The average yields of the checks and the variously treated plots in each section from 1905 to 1912, inclusive, are given in Table LVI.

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[1] Ohio Agr. Expt. Sta., Buls. Nos. 258, 273, 286.

[2] Ohio Agr. Expt. Sta., Bul. No. 260.

TABLE LVI.—*Average yields of crops in five-year rotation— Yields by sections computed according to Ohio system.*[1]

Section.	Year.	Crop.	Plots, treatment, and yield per acre.									
			Unfertilized.		Plots Nos. 18, 20, 39, yard manure.		Plots Nos. 3, 5, 9, nitrogen or potassium, no phosphorus.		Plots Nos. 17 to 33, complete fertilizer, low nitrogen.		Plots Nos. 11 to 36, complete fertilizer, high nitrogen.	
			Lime.	Floats.	Lime.	Floats.	Lime.	Floats.	Lime.	Floats.	Lime.	Floats.
Section D	1905	Corn, bushels	38. 25	35. 15	52. 86	51. 65	38. 23	34. 64	54. 67	52. 83	51. 86	49. 01
	1906	Oats, bushels	30. 21	39. 50	30. 28	43. 89	31. 95	39. 76	43. 01	46. 98	41. 86	48. 68
	1907	Wheat, bushels	12. 09	14. 09	31. 43	25. 70	11. 80	12. 61	25. 18	22. 11	29. 37	25. 62
	1908	Clover, pounds	2, 441	5, 117	3, 946	5, 226	3, 038	5, 503	3, 725	5, 325	3, 961	5, 576
	1909	Timothy, pounds	1, 853	4, 604	2, 155	4, 305	2, 091	3, 758	2, 041	4, 642	2, 383	4, 548
	1910	Corn, bushels	9. 70	17. 46	16. 15	19. 14	10. 27	18. 79	12. 60	18. 57	12. 18	19. 67
	1911	Oats, bushels	40. 36	49. 23	50. 61	54. 40	42. 20	54. 24	52. 69	58. 53	54. 08	59. 90
	1912	Do	31. 84	42. 56	43. 36	49. 29	31. 51	44. 80	43. 48	50. 67	41. 47	51. 72
Section C	1906	Wheat, bushels	3. 23	3. 52	14. 09	14. 73	4. 32	7. 11	18. 99	16. 99	19. 46	18. 44
	1907	Clover, pounds	3, 038	3, 850	4, 880	4, 897	3, 418	4, 408	4, 240	4, 101	4, 400	4, 173
	1908	Timothy, pounds	3, 084	2, 706	4, 139	3, 908	3, 056	3, 109	3, 938	3, 382	4, 171	3, 402
	1909	Corn, bushels	30. 78	33. 18	50. 34	49. 75	29. 82	39. 39	54. 49	50. 15	52. 25	45. 93
	1910	Oats, bushels	31. 62	37. 35	36. 38	42. 99	34. 56	34. 03	34. 36	38. 42	34. 11	38. 18
	1911	Wheat, bushels	6. 38	7. 31	14. 84	14. 60	5. 39	7. 37	16. 33	12. 20	14. 20	11. 18
	1912	Clover, pounds	2, 531	2, 512	5, 066	4, 894	2, 365	2, 756	4, 293	2, 808	3, 879	2, 831
Section A	1907	Corn, bushels	17. 56	23. 23	23. 49	26. 42	20. 78	26. 27	27. 16	22. 54	25. 42	29. 01
	1908	Oats, bushels	27. 90	36. 14	40. 12	54. 36	35. 11	52. 29	48. 85	60. 01	44. 90	55. 87
	1909	Wheat, bushels	11. 29	17. 26	17. 73	20. 30	11. 93	17. 85	20. 61	20. 02	20. 42	20. 07
	1910	Clover, pounds	1, 938	4, 743	3, 450	5, 347	1, 955	4, 691	3, 536	4, 760	3, 467	5, 309
	1911	Timothy, pounds	2, 301	4, 249	2, 882	4, 149	2, 125	3, 287	3, 069	4, 482	2, 871	4, 436
	1912	Corn, bushels	35. 84	43. 40	47. 95	43. 08	45. 10	52. 83	57. 35	47. 55	55. 65	56. 41
Section B	1908	Do	17. 37	18. 78	24. 99	23. 12	15. 48	20. 26	24. 35	29. 06	27. 04	27. 45
	1909	Oats, bushels	38. 56	39. 51	43. 68	43. 30	41. 25	41. 10	53. 00	58. 16	52. 23	52. 91
	1910	Wheat, bushels	8. 91	8. 13	13. 56	13. 12	10. 65	7. 22	17. 86	17. 18	18. 72	17. 09
	1911	Clover, pounds	1, 966	2, 029	2, 383	2, 902	2, 157	2, 247	1, 666	2, 877	2, 442	3, 197

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[1] Since the compilation of the above data the Ohio station has published (in Bul. No. 305) the results of further work on this same field, but the yields obtained are not given for all the plots in the experiment field. These later results, therefore, could not be incorporated in the above table.

Table LVI shows that on plots receiving no other fertilizer and also on those upon which nitrogen and potash but no soluble phosphate was used, the portion treated with "floats" gave consistently greater yields than that portion treated with ground limestone. The effect of the floats also appears to be cumulative. In regard to the plots receiving stable manure, little difference is noted between the portion treated with "floats" and that receiving applications of limestone. The floats, however, were applied after the manure had been plowed under. While no direct comparison can be made between acid phosphate and ground raw rock in this experiment it will be seen that where the soluble phosphate was employed (in complete fertilizers) in addition to the floats the yields were considerably greater than where the floats were used in conjunction with potash and nitrogen carriers only.

In Table LVII the average yields of each of the five crops of the rotation throughout the entire period of the experiment are given. These averages include six crops each of corn, oats, wheat, and clover and three crops of timothy grown in four years and averaged as four crops.

TABLE LVII.—*Average yields of crops, on plots treated with lime and floats, five-year rotation, Strongville.*

Crop.	Plots and treatment and average yield per acre.									
	Unfertilized.		Plots Nos. 18, 20, 30, yard manure.		Plots Nos. 3, 5, 9, nitrogen or potassium; no phosphorus.		Plots Nos. 17 to 33, complete fertilizer, low nitrogen.		Plots Nos. 11 to 36, complete fertilizer, high nitrogen.	
	Lime.	Floats.	Lime.	Floats.	Lime.	Floats.	Lime.	Floats.	Lime.	Floats.
Corn.................bushels..	24.92	28.53	35.96	35.53	26.61	32.03	38.44	36.78	37.40	37.81
Oats.................bushels..	33.41	40.71	40.74	48.04	36.10	44.37	45.90	52.13	44.27	51.21
Wheat...............bushels..	8.38	10.06	18.33	17.69	8.82	10.43	19.79	17.70	20.43	18.48
Clover...............pounds..	2,383	3,650	3,945	4,653	2,587	3,921	3,504	3,974	3,630	4,217
Timothy............pounds..	1,809	2,890	2,294	3,090	1,818	2,539	2,262	3,126	2,356	3,096

This table shows in a more condensed form what is shown in detail in Table LVI namely, that floats when applied liberally are effective on a soil of low phosphate content and that probably their chief function is the furnishing of phosphoric acid.

In this particular experiment the raw rock phosphate apparently became increasingly available after the soil had been plowed and cultivated for a number of years, and the finely divided rock thus more uniformly and thoroughly distributed.

The writers feel that the work of the Ohio Experiment Station shows pretty conclusively that even medium applications of ground raw rock phosphate have produced decided increases in the yield of crops, and that the efficiency of this material is increased by the mixing or composting with organic matter. The data presented by the Ohio Station, however, hardly appear to justify in the judgment of the writers a definite conclusion concerning the relative merits of raw rock and acid phosphate even under the conditions of the Ohio experimental work.

PENNSYLVANIA.

The Pennsylvania Experiment Station in 1883[1] undertook what is probably the first recorded experiment with raw rock phosphate conducted by the stations in this country. Since the work was carried on for a year only under conditions which were not controlled, the results do not warrant repetition.

A field experiment to test the fertilizer value of various phosphates was also begun by the Pennsylvania station[2] in 1883, and continued on the same field till the close of 1895, a period of 13 years.

The field selected for this experiment has a slight and uniform slope to the southeast. "The soil of the plots is a so-called limestone clay formed from the decomposition of the surrounding and underlying rock, which is largely a magnesian limestone. It has the general appearance of a clayey loam. During 1880 and 1881 the land was in grass (clover and timothy) and in 1882 in potatoes. No manure was applied to either crop." In 1883, in an effort to determine the uniformity of the field, it was divided into 12 plots of one-twentieth acre each, and planted to oats without the application of any fertilizer whatever.

In Table LVIII the average yield of the plots which subsequently received the same fertilizer treatments are given.

TABLE LVIII.—*Average yield of oats on various plots of experiment field before application of fertilizer.*

Plot letter.	Yield per acre of oats, 1883.
	Bushels.
A and G	45.94
B and H	46.56
C and I	49.38
D and J	49.06
E and K	54.06
F and L	52.81

While it has been repeatedly pointed out that the yields obtained with a single crop can not be taken as proof of the relative natural fertility of the various plots, the indications are that the average natural productivity of the check plots and those afterwards receiving only a mixture of potash and nitrogen, was greater than that of the plots on which phosphates were applied. It will also be seen that the average yield of the plots afterwards treated with acidulated phosphate was less than the average of any of the other plots.

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[1] Pa. Agr. Expt. Sta., Ann. Rept. for 1884, pp. 33–35 (1885).

[2] Pa. Agr. Expt. Sta., Ann. Repts. for 1884 (1885); 1886 (1887); 1888 (1889); 1889 (1890); 1895 (1896).

A regular four-year rotation of wheat, grass, corn, and oats was begun in 1884. The fertilizers were applied only to the wheat and corn crops, being sown broadcast after the field was plowed, and subsequently harrowed in. Muriate of potash and ammonium sulphate were applied to each plot (except the checks) at a rate supplying 100 pounds of potash (K_2O) and 47 pounds of nitrogen, respectively. The phosphates were applied at a rate supplying 32 pounds of phosphoric acid (P_2O_5). During the entire period of the experiment fertilizers have been applied six times.

The average results obtained from duplicate plots are given in Table LIX.

Table LIX.—*Average yields of various crops grown in four-year rotation on the same field for a period of 12 years (1884–1895).*

Plot letter.	Fertilizer.	Application per acre.[1]	Average yield (three years) per acre.			
			Wheat, grain.	Grass, hay.	Corn, ears.	Oats.
		Pounds.	*Bushels.*	*Pounds.*	*Bushels.*	*Bushels.*
A and G	Dissolved bone black	200	28.23	3,167	48.86	43.42
	Muriate of potash	200				
	Ammonium sulphate	240				
B and H	Reverted phosphate	200	29.89	3,300	49.60	47.10
	Muriate of potash	200				
	Ammonium sulphate	240				
C and I	Finely ground bone	150	31.58	3,365	51.96	49.39
	Muriate of potash	200				
	Ammonium sulphate	240				
D and J	Finely ground South Carolina rock	150	31.56	3,133	47.64	48.24
	Muriate of potash	200				
	Ammonium sulphate	240				
E and K	Muriate of potash	200	30.57	2,492	40.68	45.54
	Ammonium sulphate	240				
F and L	No fertilizer		22.52	2,048	33.07	38.81

[1] Applications made every other year.

Considering now the average yield of each crop from the variously treated plots during the 12 years in which the fertilizer effects were studied, we find that larger yields of wheat (grain) were obtained on the less soluble than on the readily soluble phosphate plots, and that the plots treated with raw rock phosphate compared favorably with those receiving any other form of phosphoric acid, even when the apparent natural fertility of the various plots (as determined by the crop of oats grown in 1883) is taken into consideration.

In the case of hay (grown in 1885, 1889, and 1893) the production on the plots treated with other forms of phosphoric acid showed to somewhat greater advantage than the raw rock when the apparent natural fertility of the various plots is considered, but the difference between the acid phosphate plots and those treated with raw rock was so slight as to be well within experimental error. All the phosphate plots gave considerably greater yields of hay than those receiving no phosphate.

The corn crops (1886, 1890, 1894) showed their best yields on the plots treated with finely ground bone and reverted phosphate. When the natural (apparent) fertility of the plots is taken into consideration, the acidulated phosphate plots show better yields than the raw rock plots. All the plots treated with phosphates, however, showed considerably greater yields of corn than those receiving no phosphates.

With oats, the ground-bone plots gave on the whole better yields than any of the other phosphate plots, but the raw-rock plots were not far behind and showed to considerably greater advantage than those treated with soluble phosphate.

In summing up the results of this experiment, Hess[1] of the Pennsylvania station, concludes that, considering the cost of practically equal quantities of phosphoric acid in its various forms, ground bone and raw rock phosphate gave the largest returns for the money invested, "thus indicating that the insoluble phosphoric acid is of more value as a manure than is often supposed * * *."

While the results do seem to show that raw rock phosphate had a distinctly beneficial effect on this field, the increases in yield appear to the writers out of proportion to the six light applications of this material employed, since the total quantity of phosphoric acid thus applied (provided none was removed or lost) would not be sufficient to add 0.01 per cent to the upper 9 inches of an average soil. In other words, raw rock phosphate was applied at the rate of about 54 pounds per acre per annum.

The only other work on raw rock phosphate reported by the Pennsylvania station is a laboratory experiment conducted by McDowell[2] in 1908, to test the effect of rotting manure on the solubility of a natural phosphate. This experiment is mentioned elsewhere in this bulletin.

While the field work of the Pennsylvania station seems to indicate that raw rock phosphate was effective in increasing crop yields, the increases obtained seem so out of proportion to the light applications made that the writers hesitate to attach great importance to the results. As far as they go, however, the data show as great a response from the less soluble as from the more soluble forms of phosphoric acid.

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[1] Pa. Agr. Expt. Sta., Ann. Rept. for 1895, p. 210 (1896).

[2] Pa. Agr. Expt. Sta., Ann. Rept. for 1907-8, pp. 175-178 (1908).

RHODE ISLAND.

The first field work of the Rhode Island station with raw rock phosphate was reported by Flagg and Towar[1] in 1893, and consisted of an experiment conducted for one year only.

In 1912, Wheeler[2] reported results of a three-year experiment with various phosphates. The short duration of these experiments and the absence of check plots make a repetition of the details unjustifiable.

An experiment to test the relative value of various phosphates on limed and unlimed land was begun by the Rhode Island station in 1894.[3] Hartwell[4] published a summary of the results of 20 years.

It is said that the field selected for this experiment was of uniform character, and had not been treated with fertilizer for a number of years, producing only a small crop of hay previously to the plotting of the land. The soil is Miami silt loam, composed of glacial drift of granitic origin. In 1893 the field was divided into 18 plots (the number being increased to 20 the following year), of two-fifteenths acre each, and in order to obtain an index to their natural fertility Indian corn was grown on the entire number without the application of any fertilizer whatever. The yields per plot obtained in this preliminary experiment are given in part in Table LX.

TABLE LX.—*Fertility of plots as measured by the yield of Indian corn in 1893 previous to fertilizer treatment.*

Plot number.	Yield per plot (weight of ear corn).	Relative fertility (plot 67=100).	Plot number.	Yield per plot (weight of ear corn).	Relative fertility (plot 68=100).
	Pounds.	*Per cent.*		*Pounds.*	*Per cent.*
51	159	122	52	132	107
53	124	95	54	103	84
55	140	108	56	95	77
57	142	109	58	73	59
59	127	98	60	86	70
61	79	61	62	90	73
63	111	85	64	98	80
65	114	88	66	146	119
67	130	100	68	123	100

An inspection of Table LX will show that the yields of the odd numbered plots (which were subsequently limed) were in nearly every instance greater than the even numbered plots (which received no subsequent applications of lime). It will also be seen that plots 61 and 62 which afterwards received applications of "floats" gave smaller yields of corn than any of the other plots with the exception of plots 58 and 60.

While the yields obtained in only one year can not be taken as proof of the relative natural fertility of the various plots, the indications are that plots 61 and 62 were poorer than most of the others in the field including the check or no phosphate plots.

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[1] R. I. Agr. Expt. Sta., 5th Ann. Rept., pp. 159–160 (1893).

[2] R. I. Agr. Expt. Sta., Bul. No. 148, pp. 21–29 (1912).

[3] R. I. Agr. Expt. Sta., 7th Ann. Rept., p. 122 (1894).

[4] R. I. Agr. Expt. Sta., Bul. No. 163 (1915).

In Table LXII showing the yields of crops obtained during the first period (five years) of the experiment it has been assumed that the preliminary corn crop of 1893 is an index of the natural fertility of the experiment field. This assumption may not be justified, but it serves to show what different conclusions may be drawn, depending on the method employed in comparing field results.

The actual yields therefore have been recalculated on the basis of the apparent natural fertility of the plots as determined by the 1893 corn crop. By subtracting this value from the actual yield the gain due to the fertilizer treatment has been determined and recorded under the heading "Calculated Increase."

This method of comparison is not used in the second and third periods of the experiment, since any initial inequalities in the field were probably modified by five years of fertilization.

The application of fertilizers was begun in 1894. At this time one-half of the plots (odd numbers) were limed at the rate of 1 ton per acre. Similar applications were made to the same plots in 1903, and again in 1911. The plots having even numbers have received no lime whatever during the experiment. Ample amounts of soluble potash and nitrogen carriers were applied to all plots (limed and unlimed) each year. For the first five years, 1894 to 1898, inclusive, the various phosphate carriers were applied in quantities representing at that time equal money values. In 1899, however, it was decided that in view of the fluctuations in the price of the various phosphates it would be wiser to equalize the amount of phosphoric acid on each plot. This equalization, though not completed till 1902, was brought about by ceasing the applications of the insoluble phosphates, but continuing to apply the more soluble phosphates.

From 1902, up to the close of 1913, no phosphate whatever was applied to any of the plots.

The experiment, therefore, may be divided into the three following periods: First, from 1894 to 1898, inclusive, when equal money values of the several phosphates were applied. During this period phosphoric acid was added in the form of raw rock phosphate in considerably greater quantities than in the form of the readily soluble or available phosphates. Second, from 1899 to 1902, inclusive, when the phosphoric acid applications were being equalized on all the plots; and, third, from 1903 to 1913, inclusive, when the residual effects of equal amounts of phosphoric acid in the different forms were being studied.

In the following table, which is taken from Bulletin No. 163 of the Rhode Island station, the rate of application (per one-tenth acre) of the various phosphates, up to the close of 1898, are given. The applications of all the phosphate carriers except raw rock were then continued until the amount of phosphoric added to each plot was the same. This equalization was completed in 1902.

TABLE LXI.—*Sources and amounts of phosphoric acid applied to the different plots*[1] *(1894–1898).*

Plot numbers.	Source of phosphoric acid.	Cost per ton as source of phosphoric acid.	Application of the phosphate per 1/10 acre.			Phosphoric acid applied in the 5 years, 1/10 acre.	Cost of the phosphoric acid.
			1894.	1895.	Total for 1896, 1897, 1898.		
		Dollars.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Dollars.*
51, 52	Dissolved bone black	15.00	60.0	60.0	60.0	31.8	1.35
53, 54	Dissolved bone	14.00	50.4	55.0	45.0	25.0	1.05
55, 56	Dissolved phosphate rock	13.00	92.7	120.0	73.1	44.5	1.86
57, 58	Fine ground bone	19.00	42.3	43.9	43.9	35.0	1.24
59, 60	Thomas slag phosphate	14.00	76.6	66.0	66.0	38.4	1.46
61, 62	Raw phosphate rock	11.00	92.7	94.1	94.1	73.9	1.54
63, 64	Raw Redonda phosphate	15.00	52.8	52.9	52.9	56.0	1.19
65, 66	Roasted Redonda phosphate	33.00	33.0	33.0	33.0	45.3	1.63
67, 68	No phosphate	....	....	....	....	....	....
	Double superphosphate	37.00	....	31.1	25.7	[2] 26.5	[2] 1.05

[1] The dimensions of each plot are 30 by 193.6 feet, giving an area of two-fifteenths of an acre; but, in harvesting, the crop on the edges and ends of the plot is usually eliminated and the product from only one-tenth of an acre is weighed.

[2] During four years instead of five, since double superphosphate was not included in the experiment until 1895.

At the close of the first period of the experiment it will be seen that approximately twice as much phosphoric acid had been added in the form of raw rock as in other forms. The crops grown during this period were corn in 1894, oats in 1895, and hay in 1896, 1897, 1898. The yields of the various plots are given in detail in Table LXII.

TABLE LXII.—*Yields of corn, oats, and hay obtained during the first period of experiment (1894–1898).*

[Yields given in pounds per one-tenth acre.]

Source of phosphoric acid.	Corn, 1894.				Oats, 1895.				Hay, 1896, 1897, 1898.			
	Limed.		Unlimed.		Limed.		Unlimed.		Limed.		Unlimed.	
	Actual yield.	[1] Calculated increase due to treatment.	Actual yield.	[1] Calculated increase due to treatment.	Actual yield.	[1] Calculated increase due to treatment.	Actual yield.	[1] Calculated increase due to treatment.	Actual yield.	[1] Calculated increase due to treatment.	Actual yield.	[1] Calculated increase due to treatment.
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Dissolved bone black	339	100	278	125	118	61	96	59	1,649	107	712	495
Dissolved bone	270	84	202	82	96	51	101	72	1,463	262	601	430
Dissolved phosphate rock	297	85	245	135	103	52	113	86	1,621	256	680	524
Fine ground bone	200	−14	170	76	87	36	84	63	1,771	394	948	828
Thomas slag phosphate	242	50	178	78	94	48	91	66	1,685	447	1,096	954
Raw phosphate rock	110	−10	146	42	70	41	76	50	1,699	928	832	684
Raw Redonda phosphate	108	−59	110	−4	61	21	50	22	1,129	55	385	123
Roasted Redonda phosphate	178	6	99	−71	41	0	53	11	1,568	456	392	150
No phosphate	196	......	143	......	47	......	35	......	1,264	......	203	......
Double superphosphate	......	......	......	......	82	......	80	......	1,464	......	371	......

[1] Values given in this column obtained by subtracting from actual yields calculated yields as determined by corn crop of 1893. Actual yields—(Check plot yield × relative fertility) = calculated increase.

A study of Table LXII will show that in 1894, the first year of the experiment, the plots receiving applications of raw rock phosphate gave no increase in the yield of corn, even when the probable difference in the natural fertility of the raw rock plots and the check plots is taken into consideration. The soluble phosphate plots (both limed and unlimed) on the other hand gave substantial increases in yield over the check plots. The following year (1895) the yields of oats on the raw rock phosphate plots exceeded that of the no phosphate plots by a considerable margin, and during the next three years of the first period, the yield of hay on the raw rock phosphate plots (both limed and unlimed) surpassed the yield, not only of the check plots, but of the soluble phosphate plots as well, indicating that the ground raw rock was becoming increasingly effective.

Owing to the change in the plan of the experiment the plots were again left in grass in 1899. It was intended to equalize the phosphoric acid applications on all the plots (except the checks) this year, but owing to a mistake the additions of phosphoric acid in other forms was not brought up to that already applied in the form of raw rock until 1902.

No separate figures are given for the grass crop of 1899, but in 1900 the land was plowed, treated with adequate quantities of muriate of potash and nitrate of soda, and planted to corn. The following year (1901) miscellaneous crops were grown in each series in rows extending across the plots.

In 1902, the fourth year of the second period, the plots were planted in soy beans. The results of this second period of the experiment including the years 1900, 1901, and 1902 are given in Table LXIII.

TABLE LXIII.—*Yields of crops obtained during second period of experiment (1899–1902).*

Treatment.	1900: Corn, yield per acre.		1901: Miscellaneous crops.[1]		1902: Soy beans, yield per acre.	
	Limed.	Unlimed.	Limed.	Unlimed.	Limed.	Unlimed.
	Bushels.	*Bushels.*	*Per cent.*	*Per cent.*	*Bushels.*	*Bushels.*
Dissolved bone black	71.1	54.7	304	409	27.5	23.3
Dissolved bone	75.6	63.2	327	366	29.3	26.8
Acid phosphate	78.5	70.9	250	395	27.7	25.3
Fine ground bone	84.0	69.8	329	440	29.3	27.5
Basic slag meal	79.4	65.6	336	444	29.8	27.3
Floats	82.3	67.8	243	382	26.5	23.6
Redondite (raw)	76.4	54.3	93	177	17.2	16.0
Redondite (roasted)	82.6	54.1	257	226	24.6	19.1
No phosphates	75.1	48.1	100	100	16.7	14.2
Double superphosphate	78.3	50.9	279	143	25.3	19.7

[1] Relative yields of miscellaneous crops, taking no phosphate plot as 100.

For the second year of the second period of the experiment when the plots were in corn, the raw rock phosphate plot (limed) exceeded the yields of all the soluble phosphate plots and was only surpassed in actual yield by the plot treated with fine ground bone. Raw rock also ranked among the highest of the unlimed plots, exceeding in yield the plots treated with dissolved bone black, dissolved bone and double superphosphate.

During the third year of the second period, however, when miscellaneous crops were grown the plots treated with the more available and soluble phosphates showed to greater advantage. A point unfavorable to the less soluble phosphates in this experiment is the fact that many of the miscellaneous crops were cut and weighed before maturity. Since acid phosphate undoubtedly gives greater early stimulation than the raw phosphates, the effect of the former was possibly more marked than it would have been had the crops been allowed to mature.

The results with soy beans during the fourth and last year of the second period of the experiment were also more favorable to bone meal, slag, and the soluble phosphates than to the ground raw rock, both on the limed and unlimed series, but the floats gave greatly increased yields over the no-phosphate plots. Large amounts of all phosphates, except raw rock phosphate, were added this year, in order to bring about the equalization of phosphate applications. It is rather surprising, therefore, that the plots so treated should not have given much greater increases for this year than the raw rock plots to which nothing had been added since 1898.

The third period of the experiment began in 1903, when 19 miscellaneous crops were again grown across the plots in both series, a few rows only being devoted to each crop. In 1904, oats were grown and harvested as hay, and in 1905 and 1906, the field was in hay. In 1907, miscellaneous crops were again planted across the plots. Whitecap corn and a few rows of turnips were grown in 1908. In 1909, all the plots were planted in potatoes, which were followed by rye. The rye was harvested in 1910, and Hungarian grass planted. In 1911, oats were grown followed by rowen, and in 1912 and 1913 the field was again in hay. The yields obtained from the various plots during this third period of the experiment are given in detail in Table LXIV.

TABLE LXIV.—*Yields of crops grown during third period (1903–1913).*

Treatment.	1903: Miscellaneous crops.[1]		1904: Oat hay, yield per acre.		1905: Hay, yield per plot.		1906: Hay, yield per plot.		1907: Miscellaneous crops.[1]		1908: Corn, yield of ears per plot.		1909: Potatoes, yield per plot.		1910: Rye and Hungarian hay.[1]		1911: Oats, yield per plot.		1912: Hay, yield per plot.		1913: Hay, yield per plot.		1913: Turnips.[1]	
	Limed.	Unlimed.	Limed.	Unlimed.	Limed.	Unlimed.	Limed.	Unlimed.	Limed.	Unlimed.	Limed.	Unlimed.	Limed.	Unlimed.	Limed.	Unlimed.	Limed.	Unlimed.	Limed.	Unlimed.	Limed.	Unlimed.	Limed.	Unlimed.
	P. ct.	*P. ct.*	*Tons.*	*Tons.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*P. ct.*	*P. ct.*
Dissolved bone black	555	272	3.98	2.16	634	461	367	303	204	220	445	423	1,359	903	290	270	75	97	580	290	640	440	489	1,026
Dissolved bone	740	408	4.45	3.15	570	460	320	338	219	335	465	438	1,293	1,150	263	202	68	108	550	230	580	290	255	376
Acid phosphate	641	402	4.30	3.15	555	513	350	343	207	246	416	436	1,180	1,003	233	187	72	107	535	270	570	330	126	438
Fine ground bone	741	412	3.95	3.18	538	468	368	383	242	322	426	475	1,082	1,103	249	218	46	113	545	320	570	350	312	505
Basic slag meal	656	388	4.25	3.70	593	473	353	367	222	302	422	485	1,172	1,162	266	227	48	117	590	370	580	390	269	965
Floats	319	302	3.38	2.70	540	465	350	390	192	275	408	448	987	924	193	141	85	101	510	280	560	360	293	426
Redondite (raw)	99	197	2.30	1.40	460	458	298	327	97	120	243	290	683	438	75	57	75	85	400	220	540	360	55	79
Redondite (roasted)	309	182	3.48	1.45	540	458	298	327	182	142	486	325	1,199	423	240	169	80	100	580	340	660	320	229	176
No phosphate	100	100	2.50	0.70	491	354	330	360	100	100	301	244	729	356	100	100	84	42	400	240	530	360	100	100
Double superphosphate	590	146	3.57	1.70	570	480	405	420	205	164	458	396	1,145	636	207	219	98	67	620	400	770	430	148	478

[1] Relative yields of crops taking "no phosphate" plot as 100.

Considering the results obtained during the third period of the experiment the yields of miscellaneous crops in 1903 were on the whole considerably greater on the soluble-phosphate plots and those treated with basic slag and ground bone than on the raw rock phosphate plots.

In 1904 the raw-rock plots (limed and unlimed) gave smaller yields of oat hay than any of the soluble-phosphate plots, with the exception of double acid phosphate (unlimed.) The yields of hay from the raw-rock plots, however, in 1905 and 1906 compared quite favorably with those of the other phosphate plots.

The yields of most of the miscellaneous crops grown in 1907 were greater on the soluble phosphate, bone, and basic-slag plots than on those treated with raw rock phosphate, but the average yield obtained on plots treated with the latter material were very much greater than those of the check plots.

In 1908 the yield of whitecap corn from the raw-rock plot (unlimed) was greater than that from any of the soluble-phosphate plots, but did not equal the yields of the ground-bone and basic-slag plots. On the limed series, however, the yields of corn were greater on the basic-slag, bone, and soluble-phosphate plots. The results with the few rows of turnips grown this same year on the limed series were more favorable to raw rock phosphate than to any other phosphate application, but on the unlimed series basic-slag treatment showed to much greater advantage.

In 1909 the yield of potatoes from the raw-rock plot (limed and unlimed) was exceeded by all the other phosphate plots except raw Redonda, dissolved bone black (unlimed) and double superphosphate (unlimed). The rye which was planted in 1909 and harvested in 1910 gave considerably better yields on the plots (limed and unlimed) treated with slag, bone, and the soluble phosphates than on the raw-phosphate plots. The same was true of Hungarian hay which followed rye. In 1911, however, the yields of oats on the raw-rock plots compared very favorably with the yields from the plots which had received equal amounts of phosphoric acid in other forms. The hay crops in 1912 and 1913 were somewhat better on the slag, bone, and soluble-phosphate plots than on those treated with raw rock, but the yields of turnips this same year from the raw-rock plots compared favorably with those from the plots receiving other phosphates, except dissolved bone black and basic slag (unlimed).

In summing up the results of this long-time experiment it can be said that distinct increases in yields were obtained from the use of raw rock phosphate. In nearly every case where this material was applied in quantities supplying from two to three times as much phosphoric acid as acid phosphate it compared favorably with the latter material after lying in the soil for some time (two years), and becoming thoroughly distributed through tillage and cultivation.

On bringing up the applications of slag, bone, and acid phosphate to the point where equal amounts of phosphoric acid were added to all plots except the checks, the latter forms were on the whole somewhat more effective than raw rock phosphate, particularly on the limed plots. This, however, is what might be expected in view of the greater solubility of bone, slag, and the acidulated phosphates and the greater ease with which they are distributed in the soil. Indeed, it seems rather surprising that raw rock phosphate should have given such continued increases in yield when the total quantity added in 20 years (provided none was removed by the crop grown) was sufficient to add less than 0.03 per cent of phosphoric acid to the upper 9 inches of a soil of medium texture. When using a phosphatic fertilizer, the effectiveness of which depends upon heavy applications, the use of 2,000 or 2,500 pounds per acre in 20 years seems a very light application.

A pot experiment with the soil taken from the 20 plots of the experiment field just described was undertaken by the Rhode Island station in 1905,[1] just three years after the phosphoric acid applications had been equalized on all the phosphate plots. Limed soil was taken from the odd numbered plots and unlimed soil from the even numbered plots.

The results obtained in the growing of wheat for two weeks were fairly well in accord with the field results obtained on the same soil when equal applications of phosphoric acid were employed. In both cases the beneficial effect of lime was very marked. The short duration of this experiment, however, renders detailed discussion unwarranted.

The results of the Rhode Island station's work, in the opinion of the writers, point strongly to the value of raw rock phosphate as a fertilizer. Even when applied under such adverse conditions as in the station's 20-year experiment the raw rock phosphate plots gave very marked increases over the no-fertilizer plots, and in many instances surpassed those treated with more soluble phosphates. The writers feel, however, that the data afforded by this experiment are insufficient to warrant a strict comparison of the relative merits of the various forms of phosphoric acid.

SOUTH CAROLINA.

While the South Carolina Experiment Station has reported 23 experiments with raw rock phosphate, 20[2] of these have been conducted for one year only and 2[3] for a period of three years.

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[1] R. I. Expt. Sta., Bul. No. 109 (1905).

[2] S. C. Agr. Expt. Sta., Bul. No. 5 (1889); Bul. No. 12 (new series) (1893); Bul. No. 14 (new series), p. 4 (1893); Bul. No. 18 (new series) (1894).

[3] S. C. Agr. Expt. Sta., Bul. No. 2 (new series) pp. 80–82 (1891).

A more valuable experiment with raw rock phosphate is that reported by Keitt[1] in 1914. While the results of four years' work in the growing of corn and cotton on plots treated with various phosphates alone, and in combination with other fertilizer materials have been reported, this work is said to be only preliminary and is therefore not discussed here.

None of the experiments of the South Carolina station have been continued long enough to warrant discussion and therefore no conclusions may be drawn concerning the value of raw rock phosphate as a fertilizer.

TENNESSEE.

The Tennessee station has published the results of 10[2] field experiments with raw rock phosphate. Seven of these experiments cover periods of only one to two years.

The average results obtained in three experiments covering periods of from three to four years and conducted by, or under the direction of the State station, were published by Mooers[3] in 1912. A rotation of cowpeas and wheat was practiced in these experiments and four different types of phosphate fertilizers were tested both on limed and unlimed plots.

The beneficial effect of liming on these three forms was quite marked except in the case of the raw rock phosphate and basic slag plots. The latter material appears to have been the most effective of all the phosphates, owing in part no doubt to the free lime which it contained.

If the average yields of all three forms are considered, the raw rock plots (unlimed) compare very favorably with the acid phosphate (unlimed) plots, but where lime was applied the average yields were considerably more favorable to acid phosphate.

If, however, the average yields obtained on the station farm only are considered (the experiment at this place having been conducted the longest) the raw rock phosphate plots compare favorably with those receiving acid phosphate and bone both on limed and unlimed land.

These three experiments have not been running long enough to give conclusive evidence on the relative values of the four forms of phosphoric acid used and therefore are not repeated in detail, but the indications are that applications of raw rock phosphate were effective in increasing the yield of various crops.

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[1] S. C. Agr. Expt. Sta., Bul. No. 178 (1914).

[2] Tenn. Agr. Expt. Sta., Ann. Rept. 1885–1886, pp. 100–112 (1886); Bul. No. 2, vol. 13, pp. 11–14 (1900); Bul. No. 1, vol. 16, pp. 14–16 (1903); Bul. No. 86 (1909); Bul. No. 90 (1910); Bul. No. 92 (1911); Bul. No. 96 (1912).

[3] Tenn. Agr. Expt. Sta., Bul. No. 96, pp. 15–24 (1912).

VIRGINIA.

In an article entitled "A Study of the Effect of Fertilizers on the Soluble Plant Food in the Soil, and on the Crop Yield," Ellett and Hill,[1] showed the impracticability of accurately correlating the solubility of phosphates in a certain conventional solvent with their availability to crops under soil conditions. The analytical work connected with the problem was checked against field results with corn extending over a period of five years.

The soil of the field used in this experiment was derived from the Shenandoah limestone, and consisted of a light gray (Hagerstown) loam, ranging from 6 to 10 inches in depth and underlain by a reddish yellow clay subsoil. "The cropping history of this particular soil is not definitely known, but it has probably been under cultivation for not less than 75 years." The total phosphoric acid content (0.113 per cent) was ample, though only 0.07 per cent was shown by the ordinary hydrochloric acid digestion method of analysis.

The annual application per acre of the various fertilizers and the yields of corn (grain) obtained are shown in Table LXV. Since none of the other phosphates was used in connection with carriers of nitrogen and potash, a comparison between them and acid phosphate is only possible where the latter was used alone. The results obtained on plots treated with mixtures of acid phosphate, nitrogen, and potash are, therefore, omitted in the table.

TABLE LXV.—*Yields per acre of corn obtained on plots receiving various forms of phosphoric acid (1907–1911).*

Plot number.	Fertilizer.	Application per acre.	1907	1908	1909	1910	1911	Average yield for five years.
		Pounds.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
1	Acid phosphate	600.0	46.61	45.00	42.95	37.50	30.53	40.51
2	do	200.0	41.79	48.21	41.79	30.53	34.82	39.43
3	Floats	99.6	46.61	46.61	39.64	25.71	36.43	39.00
4	do	99.6	43.93	53.35	39.11	27.32	34.28	39.59
5	Thomas slag	192.0	41.79	44.46	39.11	19.28	31.60	35.24
6	do	192.0	37.50	41.79	30.00	21.42	31.07	32.35
7	Acid phosphate	400.0	39.11	38.57	32.68	14.82	21.43	29.32
11	Check		43.93	40.18	36.96	24.64	19.29	33.00
12	do		40.71	51.43	39.64	24.10	24.10	35.99
13	do		42.86	45.00	36.43	24.10	30.00	35.67
14	do		42.86	46.61	43.39	28.92	37.50	39.85
18	Lime	1,200.0	43.93	53.57	52.50	39.65	47.68	47.46
19	Check		44.46	47.14	39.64	30.00	34.82	39.21
20	do		42.86	53.57	46.08	30.00	35.36	41.57
23	do		40.71	62.14	38.03	15.00	37.50	44.59
24	do		40.18	31.07	36.96	[1] 7.85	33.21	35.35

[1] Not included in average.

The results obtained in this experiment are very confusing. If the difference in the yields of the check plots be considered for any single year, it appears that their relative natural fertility varied greatly, yet check plot No. 23, which yielded 3 less bushels of corn than check No. 12 in 1907, exceeded the yield of this latter plot in 1908, by nearly 11 bushels. These same inconsistencies are noticeable throughout the table. The plot receiving a fair application of lime gave better yields than any of the phosphate treated plots, yet the plots treated with basic slag, which is richer in lime than any of the other phosphates, gave poorer yields than either of the "floats" plots and two out of three of the acid phosphate plots. While the raw rock phosphate plots produced on the whole better results than those treated with either of the other forms of phosphoric acid, the average yield of corn on these plots for the entire five-year period was only 1 bushel greater than the average on all the check plots.

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[1] Va. Agr. Expt. Sta. (Blacksburg). Ann. Rept. for 1911–12, pp. 116–132 (1913).

In view of the fact that the applications of raw rock were entirely too light to prove effective and moreover were only from one-sixth to one-half as great as those of acid phosphate, no comparison between the two forms of phosphoric acid would be justified even had the soil been responsive to phosphate treatment. Practically the only conclusion to be drawn from these results is that all forms of phosphoric acid were ineffective.

Ellett and Hill[1] also published the results of four pot experiments with various phosphates on different but important Virginia soil types. The tests were made in the greenhouse and were similar in all respects. Twenty-five pounds of each soil type was taken for each pot, the fertilizer added, and the whole thoroughly mixed. The moisture content was maintained in each pot throughout the experiment at about one-half the water holding capacity of each soil. The seed planted, the number of plants per pot, and the fertilizer treatments were the same for each series of pots. Every treatment was run in quadruplicate. The various soil types employed were as follows: (1) A typical Coastal Plain sandy soil, low in phosphoric acid; (2) a Piedmont "Red Lands" clay soil well supplied with phosphoric acid and potash but low in nitrogen; (3) a Piedmont chocolate-colored clay loam suitable for general agriculture, with rather high contents of potash and phosphoric acid, but low in nitrogen; (4) a Piedmont gray sandy soil lower in its content of phosphoric acid and potash than the chocolate clay loam and very poor in nitrogen.

The results of the pot experiments with these soils are given in Table LXVI.

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[1] Va. Agr. Expt. Sta. (Blacksburg). Bul. No. 200, p. 24 (1912).

TABLE LXVI.—*Yields of oats obtained in four pot experiments with various types of soil.*

Fertilizer.	Application per acre.	Yields of oats, average of four pots.			
		Coastal Plain soil.	Piedmont, Red Lands soil.	Piedmont, chocolate soil.	Piedmont, gray soil.
	Pounds.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Acid phosphate	200	37.9	42.9	37.5	38.1
Floats	120	30.9	43.2	28.6	35.7
No fertilizer	....	33.9	46.5	32.8	34.4
Nitrate of soda	100	34.1	54.6	45.2	39.1
Potassium sulphate	100	32.3	44.0	45.5	37.8
Nitrate of soda	100	34.5	50.0	47.4	51.5
Potassium sulphate	100				
Nitrate of soda	100	45.5	60.1	57.0	51.5
Acid phosphate	200				
Nitrate of soda	100	46.8	65.0	51.0	53.0
Potassium sulphate	100				
Acid phosphate	200				
Lime	....	25.8	....	....	....

With the exception of the Coastal Plain soil, the various types seemed to respond more readily to nitrogen than to phosphoric acid applications. On the basis of equal applications of phosphoric acid, however, the acid phosphate pots gave considerably better yields than those treated with raw rock phosphate, the latter material apparently producing no effect whatever. The rate of application, however, was so low,[1] and the duration of the experiments so brief, that appreciable increases in yield could hardly be expected.

In 1913 Johnson,[2] of the Virginia Truck Station, published the results of a fertilizer experiment in the growing of kale. This experiment was the outgrowth of one begun in 1908, the object of which was to determine the relative value of various fertilizer materials and the best quantities to apply, and also to determine the relative value of stable manure and clover as sources of humus both with and without lime.

The fertilizer treatment was continued over a period of five years, but the results of only one year (1913) are recorded. The ground raw rock phosphate plots compared very favorably with the acid phosphate plots, but the best yields were obtained from the use of bone products, owing probably to the nitrogen contained in the latter. However, the limited data recorded render the results of this experiment inconclusive.

The work of the Virginia station has not as yet been extensive enough to justify a comparison of acid phosphate with ground raw rock phosphate, particularly as in every experiment the applications of the latter material have been too light to get the full benefit from such an insoluble substance.

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[1] The amount of phosphoric acid applied was sufficient to add about 0.0014 per cent of P_2O_5 to the first 9 inches of a soil of medium texture.

[2] Va. Truck Expt. Sta., Bul. No. 9 (1913).

WASHINGTON AND WEST VIRGINIA.

Only one field experiment[1] with raw rock phosphate has been published by the Washington Experiment Station, and four[2] by the West Virginia station. None of these have been continued beyond one year, so they are not repeated in detail.

WISCONSIN.

Four field experiments[3] with raw rock phosphate have thus far been reported by the Wisconsin Experiment Station, but since none of them have been continued beyond two years they are not considered in detail in this bulletin.

The excellent work of Truog,[4] Tottingham and Hoffman[5] and Fred and Hart[6] on the solubility and availability of phosphates and the mutual action of bacteria and phosphates on one another is discussed elsewhere in this bulletin.

While the results of the Wisconsin station's work on ground raw rock are too limited to draw any definite conclusions, the indications point to its value as a fertilizer on peaty soils. No comparison of acid phosphate and raw rock phosphate, however, is warranted.

EXPERIENCE OF FARMERS WITH RAW ROCK PHOSPHATE AS A FERTILIZER.

While the field work of the State experiment stations is as a rule much more valuable to the student of agriculture and their results much easier of interpretation, at the same time the experience and opinions of a large number of progressive farmers who have given raw rock phosphate a fair trial, are of considerable value and worthy of serious consideration.

In order to determine the sentiment of such farmers toward raw rock phosphate a letter and set of questions was sent to each of 1,000 farmers in various parts of the country who had ordered more than one shipment of this material. It might be argued that this method of choosing names was hardly fair and on its face favorable to raw rock phosphate, since the fact that the orders for this material were repeated indicates very strongly that the consumers considered it effective. On the other hand it is probable that those who sent in but one order for raw rock phosphate reached an unfavorable decision concerning its fertilizer value before they had given it a fair trial, and therefore their opinions would be less valuable than those who had used the material through a term of years.

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[1] Wash. Agr. Expt. Sta., Popular Bul. No. 49 (1912).

[2] W. Va. Agr. Expt. Sta., Bul. No. 28, pp. 57–60 (1892).

[3] Wis. Agr. Expt. Sta., 22d Ann. Rept., pp. 275, 281 (1905); Bul. No. 147, pp. 27–34 (1907); 24th Ann. Rept., pp. 261–271 (1908); Bul. No. 202, pp. 8–11 (1911); Bul. No. 205, pp. 9–12 (1911).

[4] Wis. Agr. Expt. Sta., Research Bul. No. 20 (1912).

[5] Wis. Agr. Expt Sta., Research Bul. No. 29 (1913).

[6] Wis. Agr. Expt. Sta., Research Bul. No. 35 (1915).

Replies were received from 315 farmers, most of them in the Middle West where raw rock has been tried out much more extensively than in the East or South.

Of this number 219 or 69.6 per cent reported favorable results from the use of raw rock phosphate, 55 or 17.4 per cent were doubtful about its value, and 41 or 13 per cent regarded the material unfavorably.

Many of the responses were very incomplete and in most instances no check plots were employed. In no case was a reliable comparison made between acid phosphate and raw rock.

A summary of the data obtained is given in Table LXVII (p. 114).

SUMMARY.

Much doubt and difference of opinion exists concerning the fertilizer value of ground raw rock phosphate, but the use of this material has slowly increased until the annual consumption is now in excess of 91,000 tons.

Numerous experiments have been conducted with this material in the field, greenhouse, and laboratory, and while many of these experiments are of very little value, others warrant serious consideration. To avoid confusing the reader by a mass of data of doubtful value no field experiments of less than five years' duration have been recorded in detail in this bulletin.

The use of ground raw rock phosphate as a fertilizer in this country dates back to the early days of the South Carolina phosphate industry, but the Pennsylvania State Experiment Station recorded the first field experiment with this material in 1885. Since that date the work has been taken up by practically all of the stations east of the Mississippi River and a few of those west.

Since natural phosphate of lime or phosphorite is very resistant to weathering influences, it can not ordinarily be expected to yield its phosphoric acid readily to the soil solution, but by subjecting it to some chemical treatment by which it is rendered water soluble, its effectiveness is greatly increased. On the other hand, if the rock is ground to an impalpable powder (floats) and applied to the soil in such large quantities that an enormous surface is exposed to the action of the soil waters, a considerable amount will eventually be dissolved. Since carbon dioxide (in solution) and bacteria also affect the solubility of raw rock phosphate, it is reasonable to expect the latter to be more effective on soils high in organic matter. This effect may be expected to be particularly marked on soils of low phosphoric acid content.

TABLE LXVII.—*Summary of replies from 315 farmers in 28 States concerning value of raw rock phosphate as a fertilizer.*

State.	Total number of replies.	Farmers favoring use of raw rock phosphate.							Farmers doubtful about the value of raw rock.							Farmers against the use of raw rock.						
		Total number.	Number using it at rate of 250 pounds or more per acre.	Number applying it with organic matter.	Number using check plots.	Number using it for 1 year only.	Number using it for 2 years only.	Number using it for 3 or more years.	Total number.	Number using it at rate of 250 pounds or more per acre.	Number applying it with organic matter.	Number using check plot.	Number using it for 1 year only.	Number using it for 2 years only.	Number using it for 3 or more years.	Total number.	Number using it at rate of 250 pounds or more per acre.	Number applying it with organic matter.	Number using check plots.	Number using it for 1 year only.	Number using it for 2 years only.	Number using it for 3 or more years.
Alabama	4	3	2	2	0	0	1	2	0	0	0	0	0	0	0	1	1	0	0	1	0	0
Arkansas	1	1	(1)	(1)	0	(1)	(1)	(1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Colorado	1	1	(1)	(1)	0	(1)	(1)	(1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Connecticut	4	3	1	1	0	1	1	1	0	0	0	0	0	0	0	1	(1)	(1)	0	1	0	0
Delaware	1	1	1	(1)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Georgia	8	7	7	4	0	3	0	4	0	0	0	0	0	0	0	1	1	0	0	1	0	0
Illinois	105	79	78	39	2	7	5	64	16	16	8	0	(1)	4	1	10	10	0	0	8	1	1
Indiana	24	16	14	9	0	3	2	10	4	(1)	(1)	0	1	0	2	4	4	4	0	0	0	4
Iowa	4	0	0	0	0	0	0	0	3	1	(1)	0	1	0	0	1	1	1	0	1	0	0
Kansas	3	1	1	1	0	0	0	1	1	(1)	(1)	0	(1)	0	0	1	1	0	0	1	0	0
Kentucky	14	13	11	9	0	3	0	10	1	1	1	0	0	0	1	0	0	0	0	0	0	0
Louisiana	4	4	2	3	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maryland	4	2	2	1	0	0	1	1	0	0	0	0	0	0	0	2	1	2	0	1	0	0
Michigan	15	9	9	7	0	0	1	6	5	5	4	0	2	1	0	1	1	0	0	0	1	0
Mississippi	6	5	4	3	0	0	1	4	0	0	0	0	0	0	0	1	1	1	0	1	0	0
Missouri	6	2	2	1	0	0	0	1	1	0	0	0	1	0	0	3	2	1	0	2	0	1
New Jersey	3	2	2	1	0	1	0	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0
New York	14	8	6	7	0	2	0	6	2	2	0	0	0	0	1	4	4	3	0	4	0	0
North Carolina	15	14	12	10	0	1	3	9	1	1	1	0	1	0	0	0	0	0	0	0	0	0
Ohio	18	7	5	5	0	0	1	6	7	2	3	0	5	1	1	4	2	1	0	0	0	0
Pennsylvania	20	12	9	10	1	2	4	6	7	4	7	0	1	1	2	1	1	0	0	0	0	1
South Carolina	5	5	5	5	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tennessee	5	3	3	2	0	1	0	2	0	0	0	0	0	0	0	2	1	0	0	1	1	0
Texas	4	2	2	0	0	1	0	1	0	0	0	0	0	0	0	2	0	1	0	2	0	0
Vermont	1	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0
Virginia	14	9	7	6	1	1	1	6	3	2	1	0	1	0	2	2	2	2	0	0	0	1
West Virginia	3	2	1	2	0	0	0	2	1	1	1	0	0	0	1	0	0	0	0	0	0	0
Wisconsin	9	8	6	7	0	1	0	5	1	0	0	0	1	0	0	0	0	0	0	0	0	0

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[1] Not stated.

The problem of determining the agricultural value of ground raw rock phosphate has been attacked through the media of laboratory, greenhouse, and field experiments. The laboratory investigations may be classified under the four following heads: (1) Determination of composition of rock. (2) Methods of determining availability of phosphates. (3) Effect of fineness of division on its solubility or availability. (4) Effect of organic fermentation on its solubility and availability.

In the analysis of rock phosphate for direct application to the field it is often only necessary to determine the quantity of phosphoric acid present in the sample.

Practically all of the methods so far proposed to determine the availability of phosphates are empirical and none of them which recommend that the phosphate be kept in contact with a definite quantity of solvent for a limited time can show any sharp distinction between the amounts of phosphoric acid available and unavailable under soil conditions.

The fineness to which rock phosphate is ground has been found to have a very important influence on its solubility in certain conventional solvents as well as upon its availability to crops. Greater yields of peas, barley, rape, and oats were obtained where floats were applied than where the phosphate was applied in coarser particles. The solubility of the very finely ground material in certain conventional solvents was also found to be considerably greater than when the rock was less finely ground.

It has been pretty well demonstrated that bacteria have an appreciable effect upon natural phosphates. When bacterial activity is accompanied by the formation of acid (carbon dioxide) the solvent action exerted on the rock phosphate is quite marked. In the case of fermenting manure, however, it has been found that the manure organisms fix or absorb phosphoric acid from natural phosphates, the latter actually showing a decreased solubility after being in contact with the manure for some time. But it has further been shown that the availability of the phosphorus in the cells of such organisms is as great as that in acid phosphate. Moreover, after fermentation has ceased, the phosphorus is released in forms soluble in carbonated waters. In nearly all of the experiments conducted to determine the effect of fermentation on rock phosphate, some conventional solution, usually a weak acid, has been employed to measure the availability of the altered phosphate. It has already been pointed out that most of these solvents do not serve as indices to the phosphoric acid available under soil conditions.

The presence of decaying organic matter in the soil, accompanied as it always is by greater bacterial activity and an increased amount of carbon dioxide, is a potent factor in rendering rock phosphate available to crops.

The advantage of pot and greenhouse work lies in the fact that by the exercise of the greatest care the conditions under which the crops are grown may be, to a large extent, controlled.

The final proof of the value of raw rock phosphate as a fertilizer must rest upon field experiments. A large amount of field work has been conducted with this material under a variety of conditions, but unless the numerous factors influencing crop yields be taken into consideration the results appear very conflicting. In considering the results of field experiments, careful attention must be given to the following factors: (1) Uniformity of experiment field, (2) topography and drainage conditions, (3) physical and chemical composition of the soil, (4) previous treatment of the field, (5) climatic conditions, (6) injuries from disease, insects, and animals, (7) kind of crops grown and selection of seed, (8) rate of application and uniform distribution of phosphates, (9) methods of comparing raw rock with other phosphates, (10) effect of other fertilizers, (11) number and distribution of plots, (12) duration of the experiment.

Two hundred and thirty-two field experiments with raw rock phosphate have been reported by the State experiment stations. Of this number only the 37 experiments given detailed consideration in this bulletin were conducted for a period of five years or longer. A summary of these 37 field tests is given in Table LXVIII, but in view of the fact that nearly all of these tests were conducted under different conditions and involve the consideration of variable factors, it is obviously impossible to classify the data in such a way as to give each experiment its proper weight. The classification given in the table therefore is in some instances necessarily arbitrary.

Out of the 37 tests given in Table LXVIII, 22 were carried on with a view to comparing the relative merits of raw rock and acid phosphate. The conditions under which such a comparison was attempted varied greatly, but it may be said that in a general way 13 of these experiments or 59.1 per cent gave crop yields as favorable to raw rock as to the more soluble form of phosphoric acid. Of the 9 experiments in which raw rock did not compare favorably with acid phosphate, 2 were conducted on fields unresponsive to phosphate treatments, and 2 gave results which could be classed as either favorable or unfavorable, depending on the method of interpretation employed.

Of the 15 experiments in which no comparison between ground raw rock and acid phosphate was attempted, 11 or 73.3 per cent gave results strongly indicating beneficial effects from the applications of the former material, and 2 of the remaining 4 experiments were

TABLE LXVIII.—*Summary of results of field experiments with raw rock phosphate conducted by the State stations over periods of from 5 to 20 years.*

State.	Total number of experiments.	Experiments comparing raw rock with acid phosphate.			Experiments making no comparison of raw rock with acid phosphate.			Experiments where raw rock applications were relatively light.			Experiments where raw rock applications were liberal.			Experiments where raw rock was used in connection with organic matter.			Apparent cumulative effect.		
		Total.	Number favorable.	Number unfavorable.	Total.	Number favorable.	Number unfavorable.	Total.	Number favorable.	Number unfavorable.	Total.	Number favorable.	Number unfavorable.	Total.	Number favorable.	Number unfavorable.	Evident, number.	None, number.	Unknown, number.
Alabama	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Connecticut	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Delaware	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Florida	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Georgia	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Illinois	12	3	2	[1] 1	9	7	[1] 2	4	4	......	8	6	[1] 2	11	9	[1] 2	8	[1] 3	1
Indiana	2	2	1	[1] 1	......	......	......	......	......	......	2	1	[1] 1	2	1	[1] 1	......	......	2
Kentucky	1	1	......	1	......	......	......	......	......	......	1	1	......	1	1	......	1	......	......
Louisiana	3	3	1	2	......	......	......	2	......	2	1	1	......	......	......	......	1	1	1
Maine	2	2	1	1	......	......	......	2	2	......	......	......	......	......	......	......	1	......	1
Maryland	2	2	2	......	......	......	......	......	......	......	2	2	......	1	1	......	......	1	1
Massachusetts	2	2	1	[2] 1	......	......	......	1	1	......	1	1	......	1	1	......	......	......	2
Mississippi	2	2	1	1	......	......	......	2	2	......	......	......	......	......	......	......	......	......	2
Missouri	4	......	......	......	4	2	2	4	2	2	......	......	......	4	2	2	4	......	......
New Jersey	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
New York	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
North Carolina	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Ohio	4	2	1	[2] 1	2	2	......	3	2	[2] 1	1	1	......	3	3	......	1	......	3
Pennsylvania	1	1	1	......	......	......	......	1	1	......	......	......	......	......	......	......	......	1	......
Rhode Island	1	1	1	......	......	......	......	1	1	......	......	......	......	......	......	......	1	......	......
South Carolina	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Tennessee	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Virginia	[1] 1	[1] 1	[1] 1	......	......	......	......	[1] 1	......	[1] 1	......	......	......	......	......	......	......	[1] 1	......
Washington	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
West Virginia	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Wisconsin	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Total	37	22	13	9	15	11	4	21	15	6	16	13	3	23	18	5	17	7	13

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[1] Soil not responsive to phosphate treatment.

[2] Figures for this experiment are favorable according to one method of computation and unfavorable according to another.

conducted on fields showing little or no response to phosphate treatment.

In 21 experiments the applications of raw rock phosphate were relatively light (250 pounds or less per acre), yet 15 of these experiments or 71.4 per cent showed distinctly favorable increases in yields on the plots treated with this material.

In 16 experiments where the raw rock phosphate applications were more liberal, 13 or 81.3 per cent resulted favorably to raw-rock phosphate, and the remaining 3 experiments were conducted on soils showing little or no response to phosphate treatment.

Raw rock phosphate was applied in connection with organic matter in 23 experiments. Out of this number 18 or 78.3 per cent gave distinctly favorable results, and of the 5 remaining experiments 3 were conducted on fields unresponsive to other forms of phosphoric acid.

In regard to the cumulative effect of ground raw rock phosphate it may be said that in 17 instances (46 per cent of the entire number of experiments) there was evidence of greater availability after raw rock had been applied for a number of years. In 13 out of the remaining 20 experiments the data are not sufficient to give evidence on this point, and in 4 out of the 7 cases where no cumulative effect was shown the soils were not responsive to phosphate treatments.

In order to determine the sentiment toward ground raw rock phosphate as a fertilizer a letter and set of questions were sent to each of 1,000 progressive farmers who had used the material for one or more years. Out of 315 replies, 219 farmers or 69.6 per cent were favorable to its use, 55 or 17.5 per cent were doubtful concerning its value, and 41 or 13 per cent regarded the material unfavorably.

CONCLUSIONS.

The data presented in this paper were gathered in order that those interested in the use of raw rock phosphate might draw their own conclusions. The classification of the experimental work according to states was made so that the experience with this material in each particular locality might be studied in the least possible time. Some of the experiments, however, undoubtedly conflict and in others, results which on close analysis agree fairly well, appear on the surface contradictory. It is hoped, however, that by carefully considering the factors influencing crop yields as outlined in page 18 to page 28, and applying them to the individual experiments much confusion can be avoided and the reader be able to obtain a fairly clear idea of the value of the results.

While the writers do not wish to influence the judgment of anyone reading this paper, they feel, after carefully weighing the data contained therein, that certain general conclusions are justified.

(1) The conventional laboratory methods so far proposed for determining the availability of phosphoric acid in various phosphates, while of some use, do not necessarily serve as an index to its availability under soil conditions.

(2) Field experiments conducted for only one or two years, where the various fertilizer treatments are not replicated or where no index is given to the relative natural fertility of the various plots employed, have little or no meaning.

(3) The application of liberal and even medium quantities of raw rock phosphate to most soils produces an increase in the yields of many crops the first year.

(4) The effectiveness of raw rock phosphate depends largely on its thorough distribution in the soil, this distribution being brought about by liberal applications of very finely divided material and thorough cultivation.

(5) The presence of decaying organic matter in the soil increases the effectiveness of ground raw rock phosphate, owing probably both to greater bacterial activity and the higher content of carbon dioxide in such soils.

(6) As a corollary of (4) and (5) the effectiveness of raw rock phosphate is usually increased after remaining in the soil for a year or more.

(7) Most crops respond more quickly to applications of acid phosphate than to bone, basic slag, or raw rock phosphate. Therefore, where the early stimulation and quick maturity of the crop are the main considerations, acid phosphate is probably the best form of phosphoric acid to apply.

(8) Field experiments in which raw rock phosphate and acid phosphate are compared on the basis of equal applications of the two materials or on equal applications of phosphoric acid in the two forms result often in favor of acid phosphate (particularly when such experiments are conducted for a short period), as in order to get the maximum benefit from the natural phosphates they must be applied at a rate far exceeding that at which acid phosphate proves effective.

(9) The question whether increases in yield can ordinarily be produced more economically by applications of the soluble or relatively insoluble phosphates must be considered in a measure a separate problem for each farmer, since it depends on a number of factors of which the most important are the nature of the soil, the crop system employed, the price of the various phosphates in each particular locality, and the length of the growing season.

UNITED STATES DEPARTMENT OF AGRICULTURE

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Contribution from the Forest Service
HENRY S. GRAVES, Forester

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CLIMATE AND PLANT GROWTH IN CERTAIN VEGETATIVE ASSOCIATIONS.

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THE PROBLEM.

The relation of climate to the growth and development of vegetation is of profound importance in both practical and experimental agriculture. It is extremely useful to know the cause of successful growth and establishment, or of partial success or failure, of various species in different plant associations and under widely contrasted climatic conditions. The climatic requirements of various plant types are largely responsible for the results obtained in the case of experimental seedings and plantings of most species. Once the adverse climatic factors are definitely known, failures with plants may be largely avoided by the judicious selection of sites or of species especially adapted to withstand the limiting factors. Therefore, a series of experiments was undertaken, (a) to obtain a comparison of the climatic requirements of the main plant types, and (b) to determine, quantitatively, the relation between various environmental factors on the one hand and plant growth and certain other physiological functions on the other. The results obtained appear to be conclusive in most instances and should prove of value both in experimental and in practical agriculture and forestry.

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[1] The author is indebted to F. Merrill Hildebrandt for material assistance in procuring and assembling the data presented in this paper.

It is a matter of common knowledge that the life cycle and structural characteristics of plants are largely determined by the climatic conditions prevailing in the habitat, but the quantitative relations existing between the potent climatic factors and the vegetative activities are not well known. Though the ecologist and plant geographer have shown that a given plant association may have well-defined geographical limits,[1] which in turn are characterized by rather distinct complexes of environmental (climatic) conditions, they have not as yet definitely determined which climatic factor, or set of factors, is most influential in affecting distribution, growth, and physiological activities generally.[2] This is attributable to several conditions. In the first place, the relation of plant development to environment is exceedingly complicated and can be determined quantitatively only when the most influential physical factors are recognized, recorded, and properly interpreted. Secondly, the climatic factors of a given habitat, and, indeed, of different habitats, which have to do with the limitation of the life process, are in themselves more or less indefinite; they are highly complicated and variable, and their intensity can not always be measured fully by instruments. In the third place, methods have not been sufficiently advanced to warrant serious investigations. Owing to present lack of knowledge of the response of plant activities to climate, there is wide diversity of opinion as to how best to summarize and integrate climatic data. Temperature studies conducted by Livingston,[3] Lehenbauer,[4] Merriam,[5] and McLean,[6] and researches on soil humidity and "growth water" carried out by Briggs and Shantz,[7] Shreve,[8] Fuller,[9] and others have shown that climatic factors can not to advantage be expressed empirically. Suitable methods of integrating the potent climatic factors, as well as of recording growth and other plant functions of comparable or "standard" plants developed under the particular climatic conditions summarized, are essential steps in a successful investigation

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[1] Drude, O. Entwurf einer biologischen Eintheilung der Gewächse. (A. Shenk, Handbuch der Botanik, III, p. 487.)

[2] As a preliminary study it would be desirable to reduce the complexes of the environmental factors to their simplest form, which, under controlled conditions, might be accomplished by maintaining constant all but the factor investigated, and in this way determining the effectiveness of each. This being done, however, the combined influence would have to be integrated in order to approach conditions in nature. Further, since under natural conditions climatic factors vary widely, both in intensity and in duration, such important variations must necessarily be included in the equation.

[3] Livingston, B. E. and G. J., Temperature coefficients in plant geography and climatology. Bot. Gaz. 56: 346–375. 1913.

[4] Lehenbauer, P. A., Growth of maize seedlings in relation to temperature. Physiol. Res. 1: 247–288. 1914.

[5] Merriam, C. Hart, Laws of temperature control of the geographic distribution of plants and animals. Natl. Geog. Mag. 6: 229–238. 1894.

[6] McLean, F. T., A preliminary study of climatic conditions in Maryland, as related to plant growth. Physiol. Res. 2: 129–207. 1917.

[7] Briggs, Lyman J., and Shantz, H. L., The wilting coefficient for different plants and its direct determination. U. S. Dept. Agr. Bul. No. 230: 7–77. 1912.

[8] Shreve, F., Rainfall as a determinant of soil moisture. Plant World. 17: 9–26. 1914.

[9] Fuller, George D., Evaporation and soil moisture as related to the succession of plant associations. Bot. Gaz., 58: 193–234. 1914.

THE EXPERIMENTS.

The investigations here reported were conducted in the vicinity of the Great Basin Forest Experiment Station, located on that part of the Wasatch Mountains embraced by the Manti National Forest in central Utah. Here, from the foothills to the highest elevations, between altitudes of approximately 7,000 and 11,000 feet, three distinct plant associations (identical in this locality with vegetative types or life zones) occur. In the heart of each of these associations a type station was selected in 1913. From 1913 to 1916 the more important environmental factors were recorded, and, accordingly, the climatic characteristics of each type-zone are well known. The investigation of the influence of the weather upon the development of comparable plants, with which the present paper is chiefly concerned, was begun in 1915 and continued and extended in 1916. The types here recognized and their approximate altitudinal limits are as follows:

Sagebrush–rabbit-brush association	feet	5, 200– 6, 500
Oak-brush association	do	6, 500– 7, 800
Aspen-fir association	do	7, 500– 9, 500
Spruce-fir association	do	9, 000–11, 000

As indicated by the plants typifying the respective associations, all but the lowest are forested. No special investigations were conducted in the treeless type.

The meteorological stations are located at elevations of 7,100, 8,700, and 10,000 feet. They are all in the same canyon, and the distance between the lowest and the highest stations in an air line is approximately 5 miles. Owing to the possibility of the results being influenced by the presence of trees and other objects in the vicinity of the physical instruments and growing plants, the stations are all located in the open, on slopes dipping slightly to the south, and no vegetation is so close as to cast shadows on the instruments or potometers, except for a few minutes at sunrise and sunset. Also, the instruments and plants are placed as near together as practicable (each type station covering one twenty-fifth of an acre), so that the conditions recorded may be practically identical with those acting upon the plants.

The investigations have been concerned chiefly with (1) recording and summarizing the meteorological data, and (2) determining the relation of certain potent weather factors to growth, water requirement, and certain other physiological functions of standard plants developed under different climatic conditions. Measurements of growth and certain other activities were recorded from time to time throughout the season. The plants used in each station were a pedigreed strain of Canadian field pea (*Pisum arvense*) known as the Kaiser variety, cultivated wheat (*Triticum durum*) known as Kubanka No. 1440, and mountain brome grass (*Bromus marginatus*) native to the Rocky Mountains. The seed was supplied by the United States Department of Agriculture and was of good viability.

PREPARATION OF PLANTS.

In 1915 seed of the plants grown in the three type stations as climatic "integrating instruments" was planted directly in potometers, without previous germination. In order to insure as prompt and uniform germination as possible, the seed, prior to planting, was soaked for 36 hours in water of approximately 65° F. The object of this was to start the plants at as nearly the zero point of growth and development as possible.

Direct seeding, however, did not prove entirely satisfactory, chiefly because of the lack of uniformity in size and vigor of the resulting sprouts. In the absence of a known method of selecting seeds which would produce comparable plants, the seed used in obtaining standard plants for investigations in 1916 was first germinated and then such sprouts as appeared to be of the same size and vigor were selected for planting. The sprouts were secured by a method which was a modification of the methods employed by Schreiner and Skinner[1] and other workers of the United States Bureau of Soils. The procedure was as follows: The seeds were disinfected for 15 minutes in a 1 to 500 solution of formaldehyde in water. Following this they were washed thoroughly and soaked for 36 hours at about 65° F., and then placed in a germinator consisting of a bed of sand over which two moist blotters were laid. The soaked seeds were placed between the blotters and a constant water level was maintained in the bed of sand, by means of a Marriotte flask, at such a point that the blotters were kept well moistened but not flooded.

When the radicle was well formed the germinating seed was transferred to a second germinator. This consisted of a circular graniteware pan, 12 inches in diameter and 4 inches deep, the surface of which was covered with waxed (mosquito bar) netting held slightly above the surface of the pan by a glass rod 5 mm. in diameter, so bent as to form a frame. Into the pan a continuous flow of tap-water, the surface of which touched the netting, but never flooded it, was allowed to run. The radicles were inserted through the mesh, leaving the body of the seed partly dry. When the shoot had developed to a length of about 2½ inches the seedlings were transferred to the receptacles in which they were grown to maturity or until killed by frost.

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[1] Schreiner, O., and Skinner, J. J. Some effects of a harmful organic soil constituent. U. S. Dept. Agr. Bur. Soils Bul. 70, 1910.

PLANTING.

In order to insure luxuriant and healthy development of the plants, those observed throughout the season were grown in substantial heavy galvanized iron potometers.

To protect them from injury by animals, hail, etc., the plants were grown under wire screen of the mesh usually used on screen doors, supported by light wooden frames. These screen frames decreased the light intensity between 40 and 50 per cent.

Water was added to the potometers as needed, the need being determined by the weight of the cans. In no case was the soil allowed to dry to a point approaching closely its wilting coefficient, nor was it at any time flooded. In watering, the potometer was brought up to its original weight. The first watering was done about a month after planting and the second 15 days later. From then on it became necessary to add water about once a week in all stations and oftener in the drier situations.

THE POTOMETERS.

The potometers were 17 inches high and 14 inches in diameter, and had a capacity of 90 pounds of air-dry soil, which provided a soil mass at all times affording ample space for the proper development and spread of the roots. The cans were fitted with lids of the same material as the cans, and five holes, ¾ of an inch in diamter, were punched in each for the plants. (Fig. 1, top view.) In the center of the cover a hole 1½ inches in diameter was provided, which was used in watering and was fitted with a cork stopper and a capillary tube bent at right angles.

Before placing the lid, sufficient soil was removed in the center of the can to make room for a granite-ware receptacle 4 inches in height by 5 inches in diameter, perforated centrally in the bottom and underlaid with 1½ inches of gravel, as shown in the sectional view of figure 1. This greatly facilited the addition of water. To add the water, a flask of known capacity was inverted and the water permitted gradually to percolate into the soil.

After the lids were placed, the spaces between the rims and cans were closed by securely sealing them over with strips of surgeon's adhesive tape 2½ inches in width. The adhesive tape was then coated with shellac to prevent its loosening when wetted by rain. The method used in sealing and watering the plants was one devised by Briggs and Shantz,[1] modified somewhat to suit special conditions.

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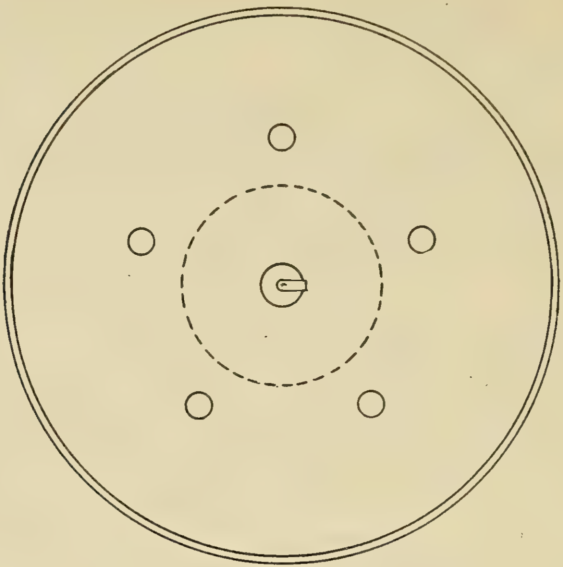
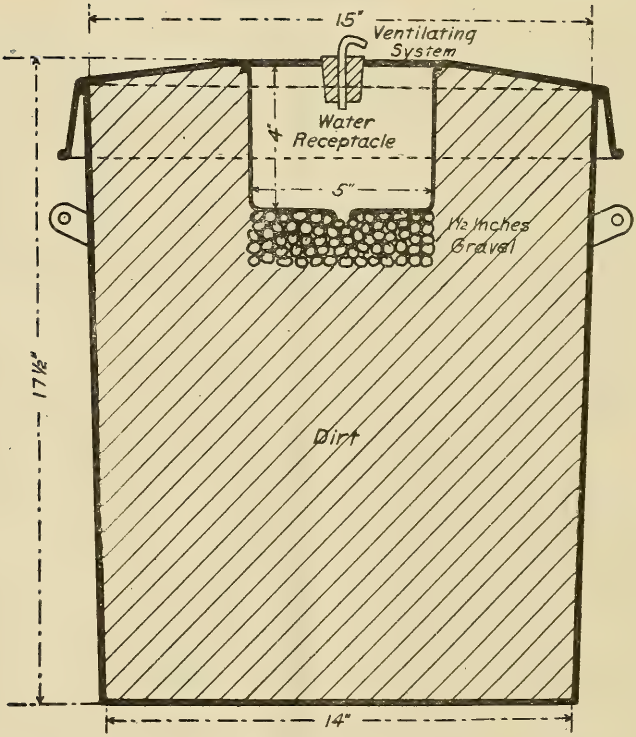
[1] Briggs, Lyman J., and Shantz, H. L. The water requirements of plants. U. S. Dept. Agr. Bur. Plant Ind. Bul. 284: 8–14. 1913.



Top View



Sectional View

FIG. 1.—Potometer used in growing plants to determine their water requirements.

THE SOIL.

The soil surface exposed by the perforations in the lids was protected from evaporation by a thin layer of wax consisting of a mixture of 3 parts of tallow and 7 parts of beeswax, applied in a melted condition.

The soil of the region is, in the main, of limestone origin, consequently soil of that type was selected. Except for the purpose of determining the relation of plant growth to soil fertility the soil used was taken from the upper 6 inches in a single situation in the aspen-fir type, and was uniform throughout all the potometers. In order to eliminate pebbles, roots, and other decomposed organic matter the soil was sifted through a $\frac{1}{4}$-inch wire mesh. Because of the presence of a large amount of clay the native soil is not so porous as was desired, and for this reason sand was mixed with it in the proportion of 5 parts of soil to 1 part of sand. The soil used was rich in humus, 5 samples averaging 12 per cent by weight after mixing with the sand. The addition of the sand reduced the wilting coefficient somewhat, the average being approximately 15 per cent.

After the soil was thoroughly mixed in the air-dry state, water was sprinkled over it until it had a " fresh " consistency; that is, the particles adhered in a lump when squeezed in the hand. Soil samples taken from each batch of soil after mixing and watering were found to average 31 per cent humidity, the variation being from 28 to 34 per cent. The moist soil was moderately tamped in the potometers, so as to prevent breaking of the roots by cracking and settling of the soil when drying. The weight of the moist soil in the potometers averaged 135 pounds.

EFFECT OF SOIL FERTILITY ON WATER REQUIREMENTS AND GROWTH.

While it has long been known that the development of the plant and the amount of water required for the production of a unit of dry matter may vary widely according to the texture and fertility of the soil,[1] it was deemed advisable to determine the difference in water requirements and growth of plants developed in soils of the same origin and texture, but differing appreciably in organic matter. The two soils investigated were of limestone origin and formed within 50 yards of each other in the spruce-fir type at about 10,000 feet elevation. They may be briefly described as follows:

(1) Infertile clay loam. The soil was well disintegrated, but owing to the destruction of most of the ground cover erosion and washing had diminished the humus content and to some extent the soluble salts.

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[1] Sachs, J., Bericht über die physiologische Thätigskeit an der Versuchsstation in Tharandt. Landwirthschaftlichen Versuchsstationen. Vol. 1 : 235. 1859.

(2) Fertile clay loam. This was of the same general texture as the less fertile soil, but owing to the presence of an adequate ground cover the soil had not been subject to washing and erosion. It appeared to be more mellow than the "infertile" clay loam and was darker in color.

The more important chemical properties at the time of the beginning of the experiment were as follows:

Soil.	Lime (CaO).	Potash (K_2O).	Phosphoric acid (P_2O_5).	Total nitrogen.	Loss by ignition.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Infertile clay loam	1.26	1.53	0.22	0.156	6.64
Fertile clay loam	1.49	1.30	.33	.488	14.65

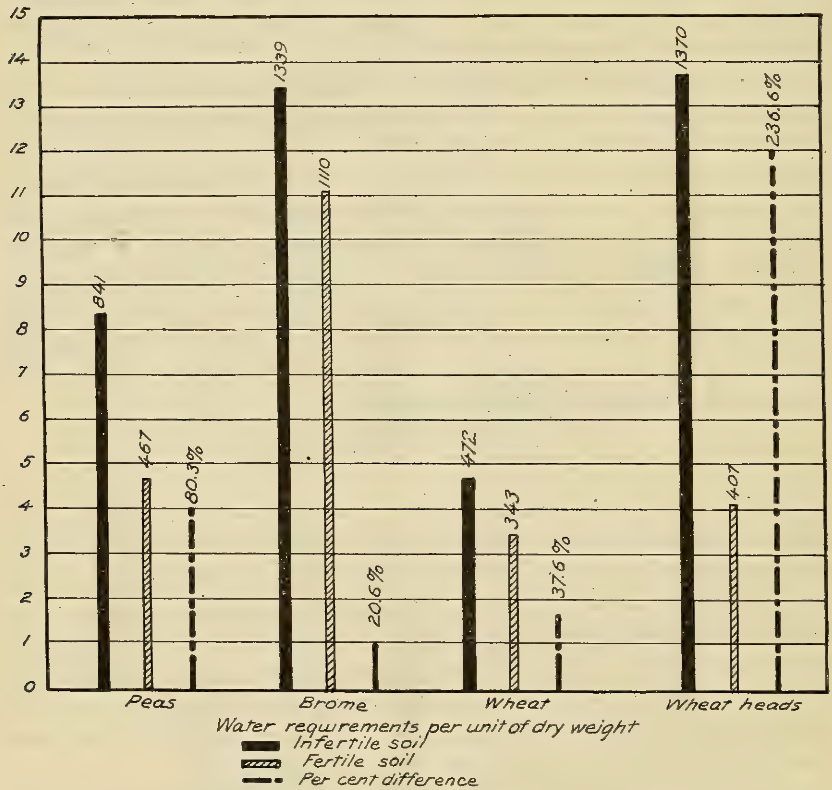

FIG. 2.—Relative water requirements per unit dry weight for peas, native brome grass, and wheat grown in infertile and in fertile soils of the same type.

The chief difference chemically was in the total nitrogen content. Also there was a wide difference in the humus content as determined by incineration. The difference in the latter was largely responsible for the contrast in the wilting coefficients of the soils, this factor being 19.3 per cent in the fertile loam soil and 15.6 per cent in the infertile loam.

After sifting and preparing the soils for the reception of the plants according to the procedure previously described, two hermetically sealed batteries of each soil type were planted with sprouts of wheat of about equal leaf area and thrift, two with Canadian field peas, and one each with mountain brome grass. Thus 10 plants each of wheat and peas, and 5 of brome grass were grown in each soil type. The potometers were placed in the meteorological station of the aspen-fir type, where the plants were grown until inclement weather set in in the autumn.

The water requirements for the production of a unit of dry matter of field peas, mountain brome grass, wheat, and wheat heads in the two soils are shown in Table 1, and graphically in figure 2.

TABLE 1.—*Water requirement in grams of peas, brome grass, wheat, and wheat heads per gram of dry matter.*

Soil.	Peas.	Brome grass.	Wheat.	Wheat heads.
Infertile soil	841	1,339	472	1,370
Fertile soil	467	1,110	343	407
Per cent difference	80.3	20.6	37.6	236.6

In all cases notably more water was required for the production of a unit of dry matter in the infertile loam soil than in the fertile loam. The difference was greater in the peas than in the brome grass or the wheat. The brome grass was less influenced than either wheat or peas. The greatest difference occurred in the production of wheat heads, there being a requirement of 237 per cent more in the infertile than in the fertile soil. Under natural conditions brome grass grows in soils of relatively low fertility, and the species succeeds in completing its life cycle in soils similar to the infertile soil here experimented with.

In summing up the total water used by the plants grown in the two selected soils it was found that a great deal more was consumed by the plants grown in the fertile than in the infertile soil, despite the fact that much more water was required by the plants grown in the infertile soil per unit of dry matter.

It is noteworthy that a wide variation exists between the water requirement per unit of dry matter of brome grass and that of peas and wheat, even when the plants are grown in the *same sort of soil.* Thus in the case of the fertile soil brome grass uses more than twice as much water as the other two species, while in the infertile soil the ratio is practically the same.[1] This wide difference in water requirement led to an examination of the character and extent of the root systems of the species in question. The examinations showed that the extent of root system varied widely, as is shown in Table 2, and figure 3.

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[1] For a review of literature bearing on the subject, see Briggs, L. J., and Shantz, H. L. The Water Requirements of Plants, II. A Review of the Literature. U. S. Dept. of Agr. B. P. I. Bull. 285. 1913.

TABLE 2.—*Relation of aerial and subterranean parts of peas, wheat, and brome grass, and comparative water requirements of aerial growth and of aerial and root development combined.*

Plant.	Weight of roots.	Weight of tops.	Ratio of roots to tops.	Water requirement per gram of dry matter.	Water requirement per gram of dry matter including roots.
	Grams.	*Grams.*	*Per cent.*	*Grams.*	*Grams.*
Peas	7.00	231.31	3.03	368	358
Wheat	8.70	264.92	3.3	358	279
Brome grass	12.82	60.11	21.3	516	413

Table 2 shows that the dry weight of the roots of peas was approximately 3 per cent of the dry weight of the tops, and the roots of wheat about 3.3 per cent; in the case of the brome grass the roots weighed 21.4 per cent as much as the tops. Hence the ratio of roots to tops in the case of brome grass was about 1:5, while in wheat and peas the roots showed a ratio of root to top by weight of about 1:30. In other words, brome grass had about six times as much root in comparison to the top as the other two species.

From these figures it would seem that the determination of the water requirement of the plant, on the basis of the dry weight of the aerial growth, is not necessarily an index to the ability of the plant to grow successfully in dry situations. To determine the moisture-absorbing power of a species account must also be taken of the depth and spread of the root system, as the volume of soil through which the roots penetrate is of the utmost importance in determining not only the amount of water available to the plant but the amount required by the tops. A plant may have a high water requirement when it is calculated on the basis of the weight of the tops, but at the same time it may be possessed of a root system great enough to supply the water necessary to the tops through its increased power to absorb. When the total water transpired by the plant is charged to the dry weight of the plant as a whole—that is, both aerial and subterranean parts—the water requirement data per unit of dry matter are quite different from those calculated on the aerial basis, as is shown in figure 3.

Since two factors, (1) water requirement, or expenditure, and (2) water gathering, or accumulation, are involved in the development of vegetation, further investigations may prove that the determination

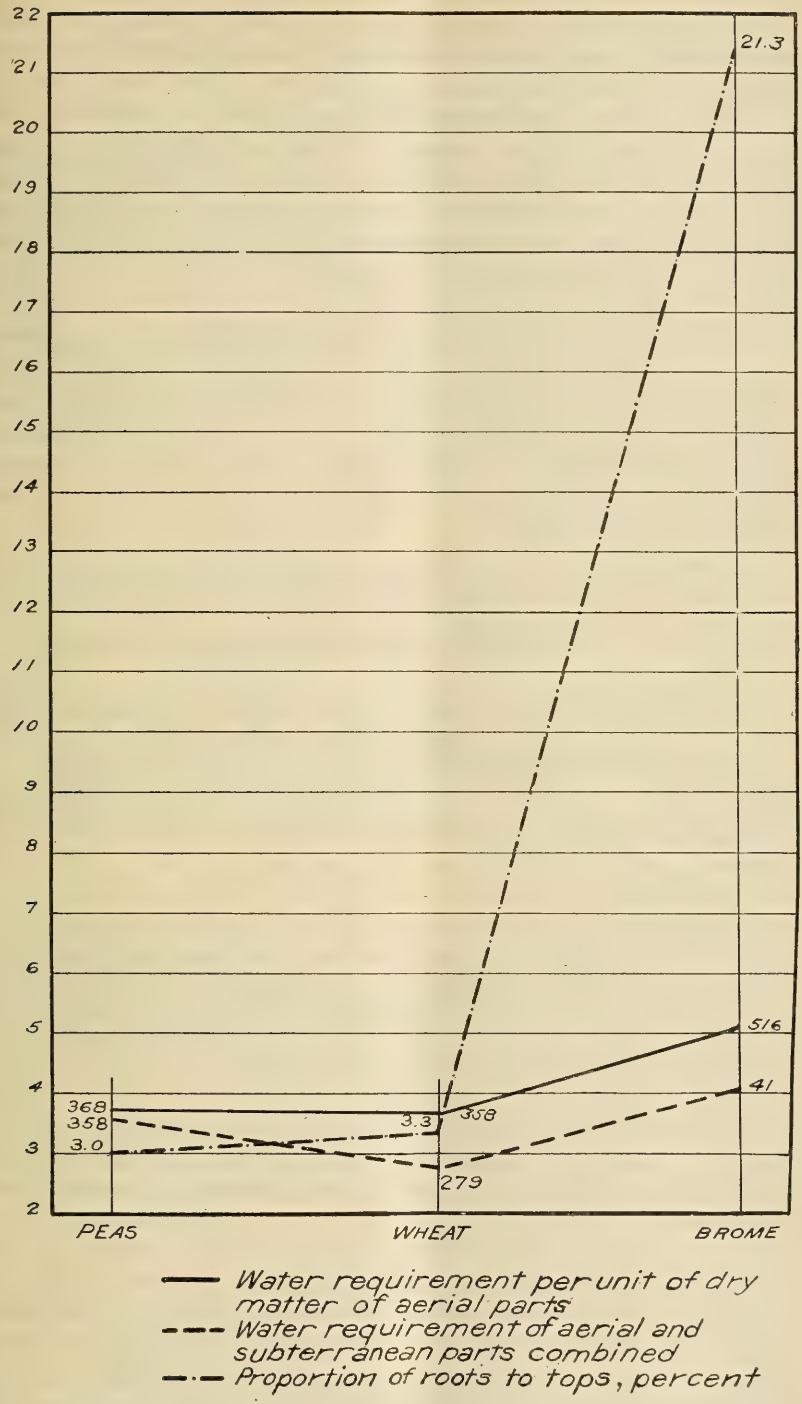

FIG. 3.—Water requirement of aerial and subterranean parts of peas, wheat, and brome grass, compared with the ratio of roots to aerial portion.

of water requirement on the basis of the plant as a whole may afford a more reliable index of successful growth in relation to drought than taking into account only the aerial portion of the plant. Most of the work on water requirement has been done in connection with cultivated plants, the root systems of which are small as compared with certain native species which may be classed as conservative users of water. The more dissimilar the root systems of species compared the less reliable the water requirement data will be unless the roots as well as the tops are taken into account.

The appreciably greater amount of water used by the plants grown in the fertile soil over those grown in the infertile soil is accounted for by the fact that the plants grew much more luxuriantly in the richer soil; hence the transpiration was much greater, and at the end of the season much more dry matter had been produced on the fertile than on the infertile soil. Exact data as to the vegetative development and the total water requirements of the species grown in the two soils are shown in Table 3.

TABLE 3.—*Summary of vegetative growth and water requirements of peas, brome grass, and wheat.*

Data determined.	Peas.		Native brome grass.		Wheat.	
	Infertile soil.	Fertile soil.	Infertile soil.	Fertile soil.	Infertile soil.	Fertile soil.
Number of leaves	42	112	35	84	22	47
Leaf length (mm.)	791	2,634	2,902	5,218	4,474	10,080
Dry weight (grams)	0.79	6.55	0.41	0.85	5.52	12.09
Water used per plant (grams)	667	3,051	553	944	2,516	3,820
Water requirement per unit dry matter (grams)	841	467	1,367	1,110	472	343

The graphical representation (fig. 4) of Table 3 shows remarkable contrast in the vegetative growth and total water requirement of the plants developed in the two soils. The number of leaves produced by field peas, for example, in the infertile soil as compared with that of the fertile soil is as 1 to 2.7; the leaf length, 1 to 3.3; the total dry weight produced, 1 to 8.3; and the water used per plant, 1 to 4.6. Similar contrasts are shown in the case of the other two species. The ratio in the water requirement per unit of dry matter, on the other hand, is reversed in the case of each species, as has previously been shown.

The above data show clearly the importance of exercising the greatest care in the selection and subsequent treatment of soils for the study of comparative growth of standard plants as a means of integrating climate. While soils obtained within a limited space and at the same depth, and having uniform appearance in color, texture, and other essentials, may be similar in many respects, they

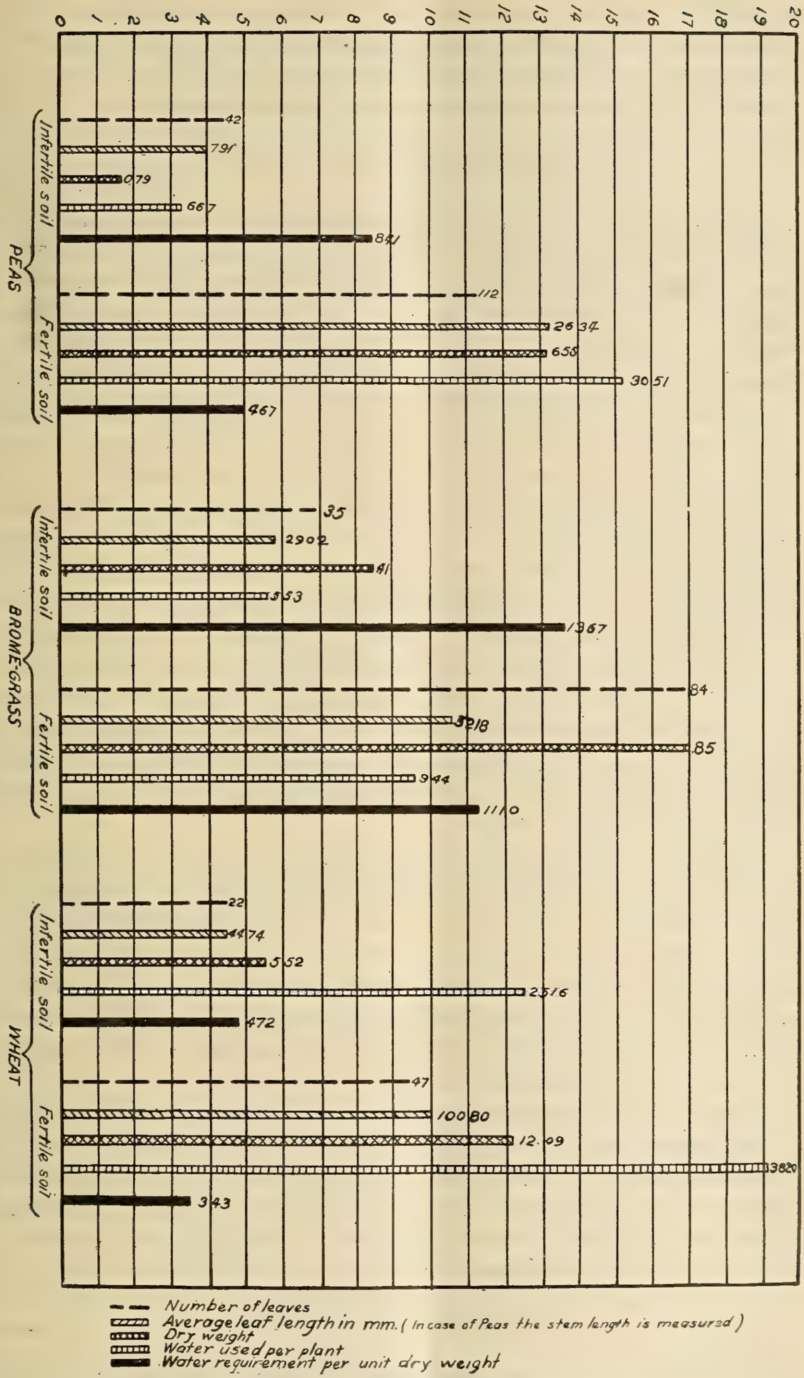

FIG. 4.—Summary of vegetative growth and water requirement of peas, native brome grass, and wheat in infertile and in fertile soils.

may differ appreciably in their crop-producing potentialities. Thorough mixing of the soil, therefore, regardless of the care with which it has been selected, can not be overemphasized as a means of avoiding outstanding errors from this source in experimentation.

MEASUREMENT OF PLANTS.

At each of the type stations measurements of growth were made on the following number of specimens: 20 of wheat, 10 of peas, and 5 of native brome grass. The lid of each potometer contained five evenly spaced perforations (fig. 1). In the case of wheat, 10 seedlings were planted in each pot, 2 in each perforation; while in the case of peas and brome grass, each pot contained only 5 plants.

Throughout the growing season both leaves and stems of the plants were measured at regular intervals. The object of the measurements was to obtain data as to the relation of the environment to (1) the tendency of the plants to elongate their stems and (2) the tendency of the plants to expand their leaves. Measurements of the stems furnished direct data as to the rate of elongation of the plants. In obtaining leaf expansion, however, indices had to be used instead of actual figures on leaf area. Hence in the case of the grasses the leaf expansion was obtained by recording the length of the leaves; for, as will be shown in the calculation of the experimental error, leaf length is proportional to leaf area. In the case of the peas, an index of leaf area was obtained by recording the number of leaflets, as they were found to be of rather constant average size and were considered as units of area.

Since the seedlings were all of uniform size and inconsiderable in comparison to the subsequent growth of the plant, the measurements were considered as beginning at zero. During the first half of the growing season all the plants were measured at 10-day intervals. Owing to the number of plants grown and their luxuriant development, it became impossible in the first week in August to remeasure all of the plants at 10-day intervals; so from then on the measurements were made once a month.

At the end of the growing season in each type the plants were cut at the junction of the stem and the lid of the potometer, and the measurement again recorded. In addition, the dry weight and the ash content were determined. In the case of plants grown in the aspen-fir association, the soil was washed away from the roots and the dry weight of the latter obtained.

EXPERIMENTAL ERROR.

In determining the rates of growth and other physiological activities for a given species some variations are sure to be found in individual specimens or in plants grown in a single battery. These variations may be due to such features as slight differences in the fertility of the soil, but mainly they are accounted for by the natural tendency of individual plants to vary. In order to eliminate such individual variations, it is necessary to average the results secured from a large number of plants. In the present experiment the number of plants was sufficiently large to render the probable error of the average measurements of any battery at a given station much less than the difference in measurements between the plants of this battery and those of the corresponding batteries of the other stations. This fact is brought out in Table 4.

TABLE 4.—*Comparison between average error of the plant measurements at a given type station and the difference in experimental results of the respective type stations.*[1]

Plant.	Type station.	Plant measurements.	Error in average.	Per cent average error.	Difference between measurements at type stations.
		Mm.	*Mm.*		*Mm.*
Brome grass [2]	Oak-brush	12,569	1,358	10.80	
	Aspen-fir	19,103	2,708	14.12	6,534
	Spruce-fir	5,064	818	16.13	14,039
Wheat [2]	Oak-brush	2,420	141	5.82	
	Aspen-fir	4,296	290	6.75	1,876
	Spruce-fir	3,359	136	4.04	937
Peas [3]	Oak-brush	155	6	3.85	
	Aspen-fir	127	4	3.10	28
	Spruce-fir	57	2	3.50	70

[1] The formula used in Tables 4 and 5 in deriving the *average error of the mean* is: the summation of all the variations from the mean, regardless of sign, divided by the number of cases times the square root of the number of cases.

[2] Average leaf length per plant.

[3] Average stem length per plant.

Table 4 shows the average leaf length (which is taken to represent leaf area) of typical specimens of mountain brome grass and wheat, and the average stem length of specimens of field peas grown in the respective type stations. From these data are computed the variations from the mean, the percentage of average error, and the difference between the measurements obtained at the type stations.

The greatest experimental error occurs in the case of mountain brome grass. This is accounted for by the fact that only 5 specimens of brome grass were grown in each type station, while in the case of the peas and wheat 10 and 20 specimens, respectively, were grown at each station. In each instance, however, the experimental error due to individual variation within a type is much less than the difference between two groups of different types.

Another source of error is the use of indices of leaf area instead of actual leaf area. Thus when the total length of the leaves of a wheat plant is used for comparative purposes, it is assumed that the total leaf length is proportional to the total area of the plant. The leaves of grasses are approximately triangular in shape, and their actual area may therefore be determined by multiplying the length of the leaf by the width and taking half of the product thus obtained. In order to ascertain whether the leaf length was a reliable index of leaf area, the leaf area was obtained in the manner described above for a number of cases and the results decided by the corresponding leaf lengths. Table 5 gives the leaf length, calculated area, the ratio of these two, the average error in millimeters, and the per cent determined by means of the formula given in the footnote to Table 4.

TABLE 5.—*Relation between leaf area and leaf length in wheat and mountain brome grass.*

Specimen.	Total leaf length.	Total leaf area.	Leaf area. / Leaf length.	Variation from mean.	Per cent variation from mean.
Wheat:	*Mm.*	*Sq. mm.*		*Mm.*	
1	1,386	3,298.00	2.3795	0.0690	2.8
2	1,147	2,806.25	2.4465	.0020	.8
3	1,127	2,526.25	2.2415	.2070	8.4
4	1,590	3,970.75	2.4973	.0488	1.96
5	1,374	3,679.25	2.6777	.2292	9.41
Total	6,624	16,280.50	12.2425	.5560	
Mean			2.4485	.0500	2.45
Brome grass:					
1	1,771	4,766.50	2.6910	.2570	8.71
2	1,279	3,334.00	2.6060	.3420	11.2
3	1,696	5,397.50	3.1820	.2340	8.61
4	571	1,837.25	3.2170	.2690	9.13
5	1,440	4,389.00	3.0470	.0990	3.35
Total	6,757	19,724.25	14.7430	1.1930	
Mean			2.9480	.1070	3.63

The fact that the ratio of leaf area to leaf length is nearly constant shows that the length furnishes a reliable index of area. The average error of the ratio for wheat, using 5 plants with about 25 leaves in all, is 2½ per cent; while in the brome grass, using 5 plants with about the same number of leaves as the wheat, the error is about 3½ per cent.

MEASUREMENT OF PHYSICAL FACTORS.

Each of the three type stations was equipped, in the main, with automatic instruments. Air temperature, precipitation, evaporation, relative humidity, sunshine, and barometric pressure were recorded continuously at each station. In addition, a continuous record of the wind movement was obtained at the two upper stations. The readings of all instruments were recorded daily at 8.30 a. m. and 4.30 p. m.

Because of the fact that certain important weather factors may be measured by various instruments, it is possible to get a number of different sets of values for the climatic factor, depending on the kind of instrument used. Where it is desired to compare physiological activities of plants with weather factors for short intervals, such as a few days, a single day, or a fractional part thereof, the kind of instrument used is often a matter of important consideration. The bearing which the choice of instruments has on the results obtained from the measurement of two of the climatic factors, evaporation and sunshine, is described in detail on pp. 18–24.

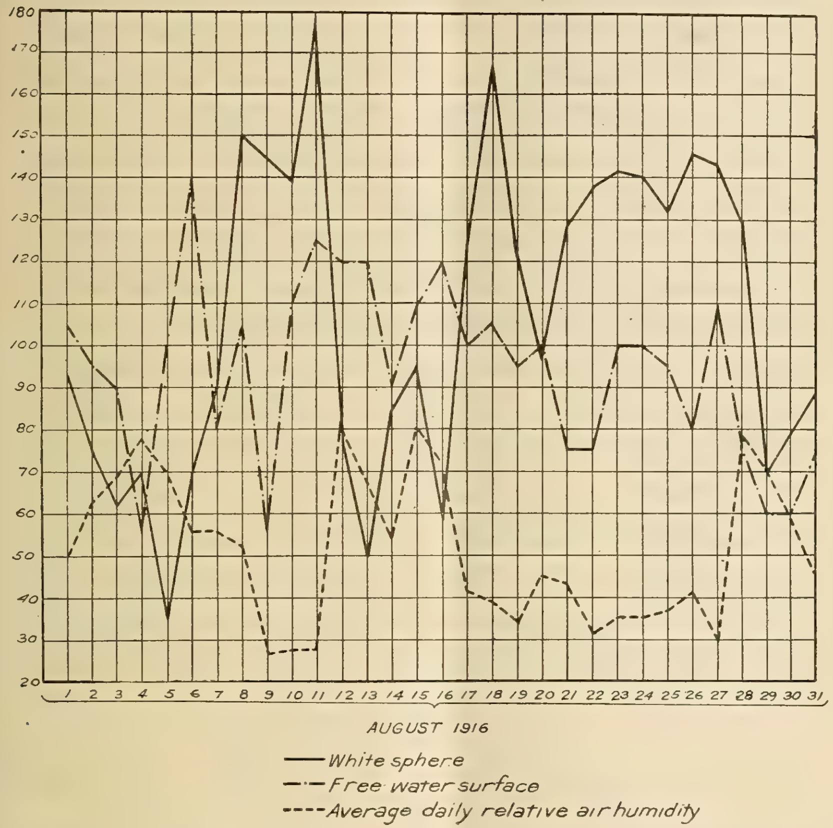

FIG. 5.—Evaporation from white sphere and from free water surface compared with average daily relative air humidity.

AIR TEMPERATURE.

The temperature was measured automatically by carefully adjusted thermographs calibrated with standardized maximum and minimum mercury thermometers and exposed in shelters of the Weather Bureau pattern 4½ feet from the ground.

PRECIPITATION.

The precipitation record was obtained by means of automatic tipping bucket rain gauges, the data from which were harmonized with standard rain gauges. In this way reliable data were obtained as to the amount and rapidity of the rainfall.

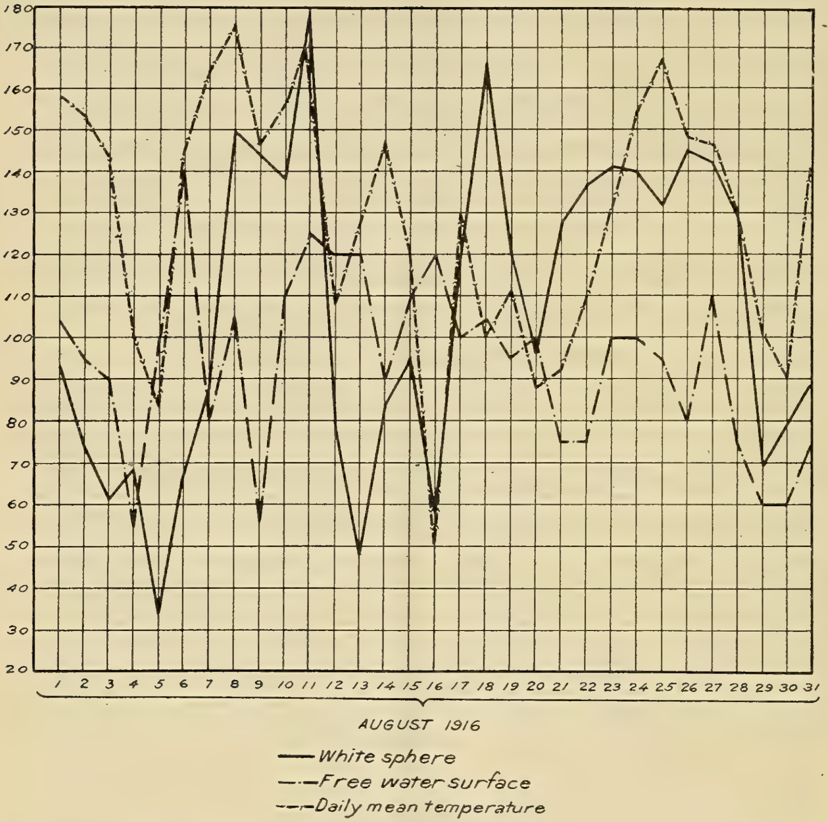

FIG. 6.—Evaporation from white sphere and from free water surface compared with daily mean temperature.

EVAPORATION.

The evaporation was recorded in two ways: (1) By means of the standardized porous cylindrical and spherical atmometers, and (2) by means of a free water surface.

In the case of the porous spheres, both the black or radio cup and the white cup were used at each station. The spherical, as well as the white cylinder cups, were fitted with rain-correcting apparatus and the mountings were self-contained as devised by Shive.[1] Distilled water was used, but in order further to insure accurate and comparable readings, the spheres, after a month of exposure, were replaced by restandardized spheres.

In measuring the evaporation from a free water surface a galvanized-iron evaporating pan, 10 by 36 inches, of the Weather Bureau pattern, was used. The evaporation from this free water surface was recorded by means of a hook gauge, reading in hundredths of an inch.

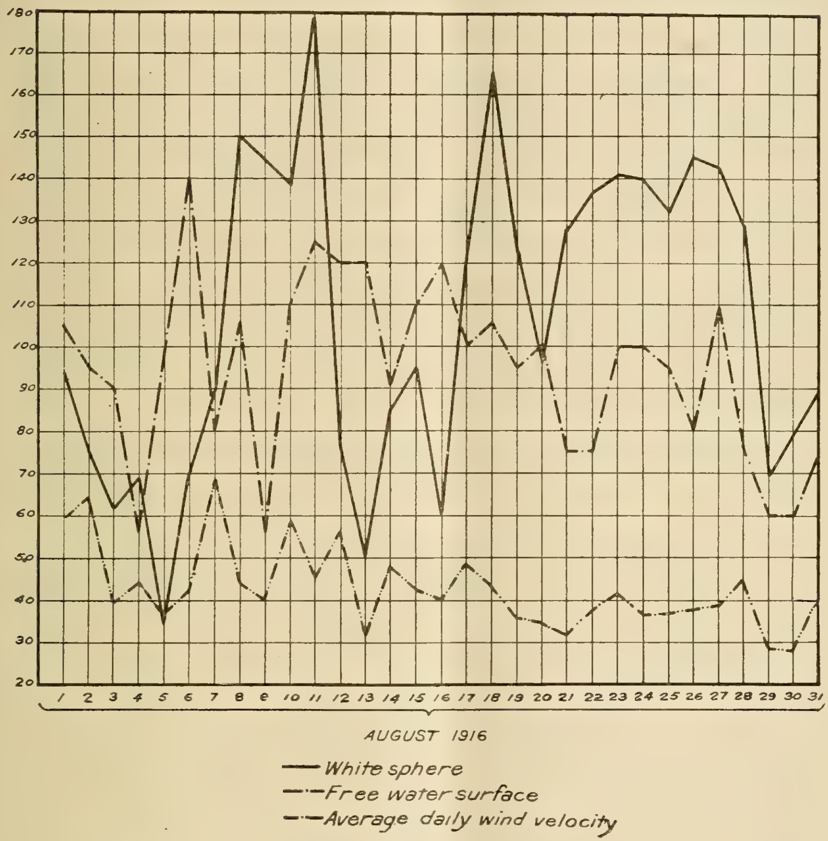

FIG. 7.—Evaporation from white sphere and from free water surface compared with average daily wind velocity.

In order that the evaporation records obtained from the two types of instruments used might be compared directly, the porous spheres and the free water surface were placed at the same height, namely, $2\frac{1}{2}$ feet above the ground.

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[1] Shive, John W., An improved nonabsorbing porous cup atmometer. Plant World, vol. 18, No. 2 : 7–10. 1915.

Probably the variations in the measurements made with different instruments are greater in the case of evaporation than in the case of any other factor. Because of the lack of information as to the accuracy of certain available instruments in the measurement of evaporation, two different sets—the free water surface pan of the Weather Bureau pattern and the porous cup atmometer—were used in obtaining evaporation indices for comparison with plant activities, and it will be helpful in future field studies to compare the results.

As it was desirable to correlate evaporation and physiological activities for short periods, the evaporation values obtained from the readings of the spherical atmometer were first compared with those obtained from the free water surface and the data from each were then compared with the factors which chiefly determine the evaporation rate, namely, air humidity, wind movement, and air temperature. By this means it should be possible to show which of the two instruments is responding best to the conditions controlling evaporation. The records as obtained in the aspen-fir type for August were selected for this purpose. The data are presented in Table 6, and as a matter of convenience in comparing, they are summarized graphically in figures 5, 6, and 7.

TABLE 6.—*Daily evaporation from spherical atmometer and from free water surface, with corresponding relative humidity, temperature, and wind velocity.*

Date.	Spherical atmometer.	Free water surface.	Average daily relative humidity.	Daily mean temperature.	Average daily wind velocity.
1916.	*cc.*	*Inches.*	*Per cent.*	*° F.*	
Aug. 1	18.8	0.21	50	65.9	5.9
2	15.0	.19	63	65.6	6.5
3	12.1	.18	69	64.4	3.9
4	13.6	.11	78	60.1	4.4
5	6.8	.20	70	58.4	3.7
6	15.3	.28	56	64.4	4.2
7	17.8	.16	56	66.4	6.9
8	29.9	.21	53	67.6	4.4
9	28.8	.11	27	64.6	4.0
10	27.5	.22	28	65.6	5.9
11	36.7	.25	28	67.1	4.6
12	15.3	.24	81	60.8	5.6
13	9.8	.24	67	62.7	3.1
14	17.0	.18	54	64.6	4.9
15	18.9	.22	81	62.1	4.3
16	11.6	.24	72	55.0	4.0
17	24.5	.20	42	63.2	4.9
18	33.2	.21	40	60.0	4.4
19	24.2	.19	35	61.1	3.6
20	19.2	.20	46	58.8	3.5
21	25.5	.15	44	59.2	3.2
22	27.4	.15	32	60.8	3.8
23	28.2	.20	36	63.0	4.2
24	27.9	.20	36	65.4	3.7
25	26.4	.19	37	66.7	3.7
26	28.9	.16	42	64.8	3.8
27	28.5	.22	30	64.6	3.9
28	25.7	.15	79	63.1	4.5
29	13.8	.12	69	60.1	2.9
30	16.0	.12	59	59.0	2.8
31	17.7	.15	45	64.3	4.1

The evaporation from the white spherical atmometer and the free water surface and the average daily relative humidity are shown in figure 5. In order to determine which of the evaporation curves is the most reliable for the periods under consideration, so far as relative humidity is concerned, note was taken of the number of cases in which the evaporation curves slope in a direction opposite to the corresponding humidity curve. As the relative humidity decreases, evaporation, other things being equal, would increase; hence it would be expected that the graph of instrumental evaporation values would show an opposite slope direction to the graph of relative humidity. For the graph representing the free water surface evaporation the slope is opposite on 19 days out of the 30, or in 63 per cent of the cases. The graph of evaporation from the spherical atmometer, on the other hand, slopes opposite to the relative humidity graph in 73 per cent of the total number of cases. In deriving these percentages, in the case of both evaporation graphs, it was deemed advisable to consider slopes as opposite in those cases in which they came very near being so, as well as when they were actually opposite. Since the evaporation curve for the spherical atmometer shows more cases of slope opposite to the relative humidity curve than does the evaporation curve for the free water surface, it may be considered that the atmometer is somewhat more reliable than the free water surface in determining evaporation for daily periods, in so far as evaporation is determined by relative humidity.

A comparison of the evaporation values obtained from the two instruments with the daily mean temperature is presented in figure 6. In this instance it would, of course, be expected that the evaporation curves would show agreement in slope with the curve representing the mean temperature. Examination of the graphs shows for the atmometer 67 per cent agreement (20 periods out of 30) with the temperature curve; and for the free water surface only 47 per cent (14 periods out of 30). If only slight disagreements between evaporation and temperature are considered, the per cent of agreement in the case of the atmometer record is even greater than that from the free water surface. It is interesting to note that the evaporation record obtained from the free water surface commonly lags about one day behind that of the temperature; that is to say, if the evaporation from the free water surface is compared with the temperature for the preceding period there is a much closer agreement than when the comparison is made for the same day. In order to obtain an evaporation record which is comparable with the transpiration of the plant for short periods, the instrument with which the evaporation is measured should respond quickly to temperature changes in a manner similar to the transpiration of the plant itself, so that for this purpose the atmometer is superior to the free water surface.

Figure 7 shows the relation of evaporation, as obtained by the two methods, to wind movements. Here, again, agreement between the two graphs consists in a slope in the same direction, since high wind velocity accelerates evaporation rate and low wind velocity retards it. This figure shows an agreement of 11 periods in the case of evaporation from the free water surface with the average daily wind movement, or a percentage agreement of 37. The evaporation from the atmometer, on the other hand, shows for the same time an agreement of 18 periods, or a percentage agreement of 60.

From the above comparisons it is evident that the evaporation record obtained by means of the spherical atmometer agrees more closely with the relative humidity, the temperature, and the wind velocity, and is a more reliable index when short periods are to be considered than that obtained from the free water surface. When periods extending over several days or longer are considered, however, either instrument may be used with good results.

Because of the advantage of the rain-correcting device used in connection with the porous cup atmometer, this instrument was especially suited to the experiments here presented, and accordingly has been used throughout. Of the three types of porous cup atmometers available for field use, namely, the white sphere, the black sphere, and the white cylinder, all were operated in each type station throughout the season. The sum of the daily means of each set of cups and the difference in evaporation between the black and white sphere are presented in Table 7.

TABLE 7.—*Summary of evaporation from white cylindrical, white spherical, and black spherical atmometers, and of difference between white and black spherical atmometers during the period of experimentation.*

Type.	White sphere.	Black sphere.	White cylinder.	Difference between black and white spheres.
	cc.	*cc.*	*cc.*	*cc.*
Oak-brush	3,956.3	5,475.0	3,545.4	1,518.7
Aspen-fir	2780.3	4,025.4	2,490.8	1,245.1
Spruce-fir	4,251.3	5,530.2	3,711.7	1,278.9

The figures given in Table 7 are platted in figure 8. It is interesting to find that the graphs representing the three evaporating instruments here used are all practically parallel. This parallelism also holds for shorter periods, as is shown in figure 9. It would appear, therefore, that one might select any one of these instruments to ascertain the evaporation. However, because of the desire to use evap-

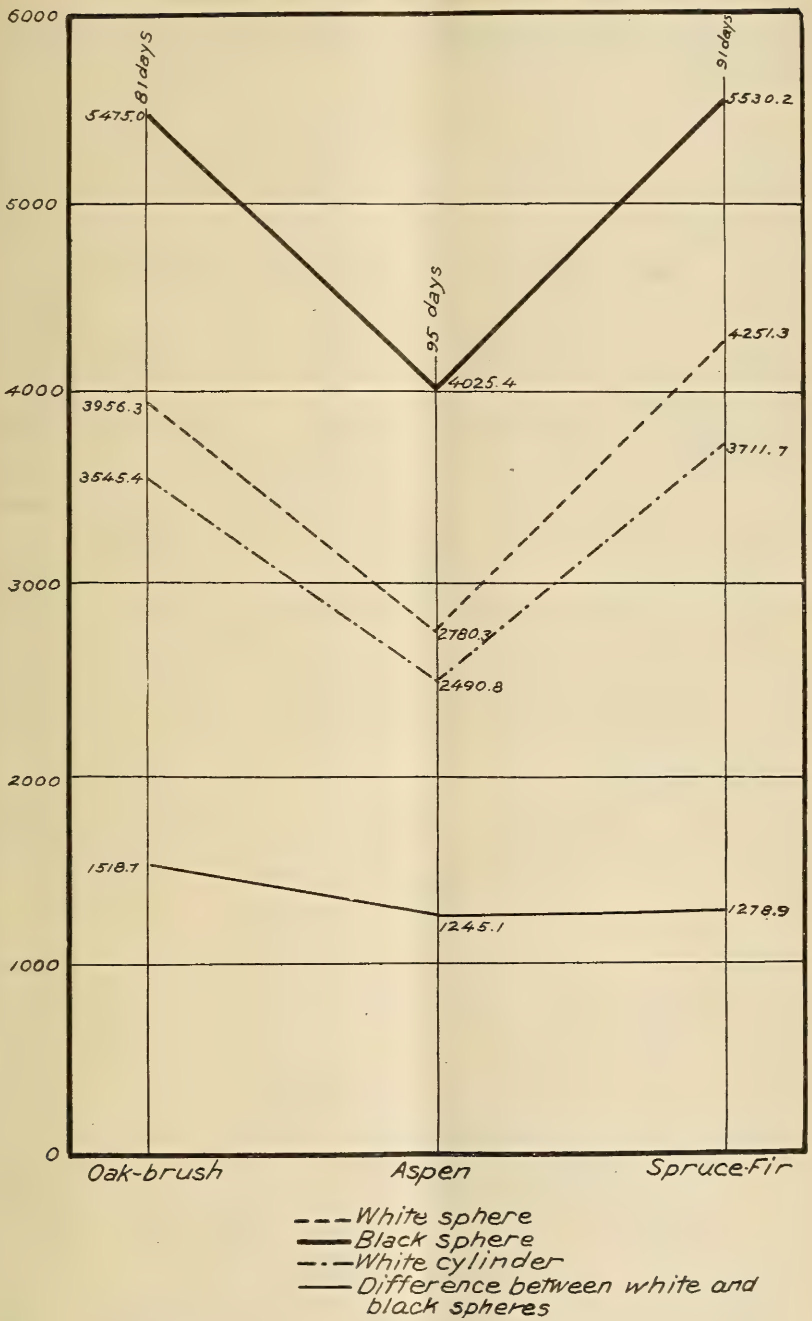

FIG. 8.—Summation of evaporation from white cylinder, white sphere, and black sphere and of differences between white and black spheres.

orating instruments which might also furnish data on sunshine intensity, the evaporation data from the white and black spherical atmometers have been used in connection with the plant studies.

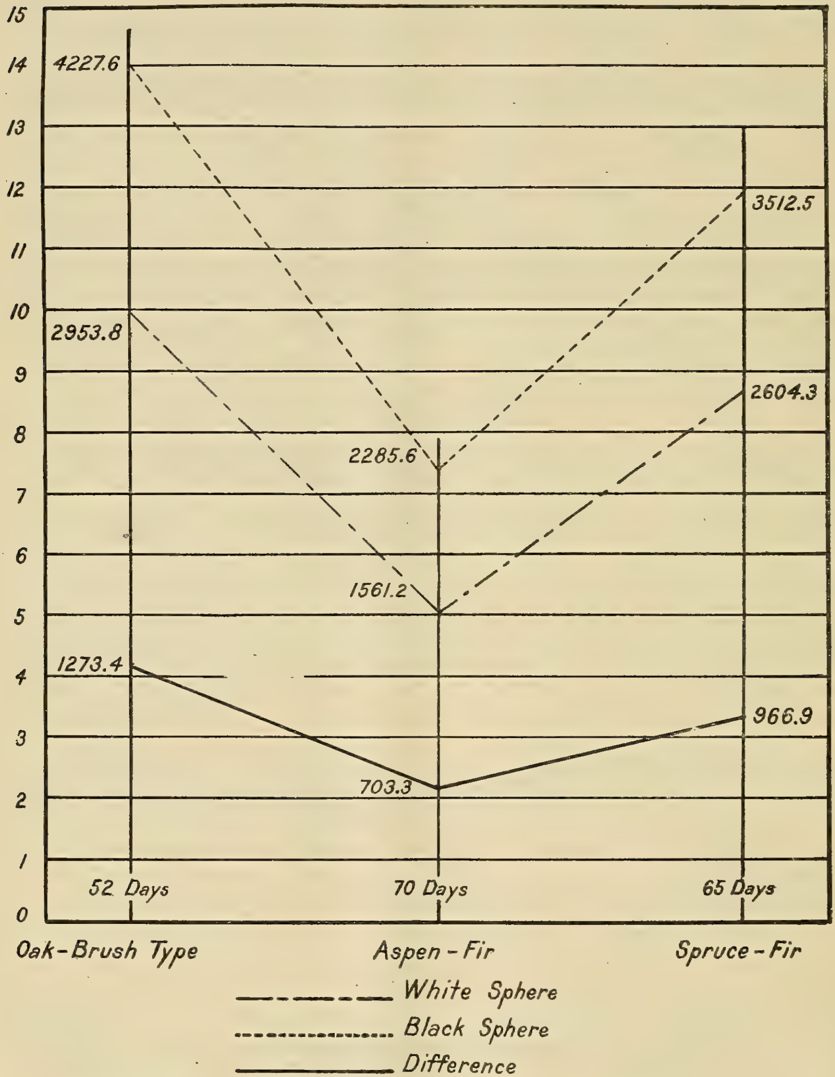

FIG. 9.—Summation of evaporation from black and white spheres and the difference between them. Record made during growth studies. Started late.

BAROMETRIC PRESSURE.

The barometric pressure was measured by aneroid barometers. The instruments were standardized from time to time at the central station, where the elevation and pressure were known.

WIND VELOCITY.

The wind velocity was measured automatically by anemometers of the Weather Bureau pattern located about 15 feet above the ground.

SUNSHINE.

The records of sunshine obtained were for both duration and intensity.

The duration of sunshine was recorded automatically by means of the Marvin recorder used by the Weather Bureau.

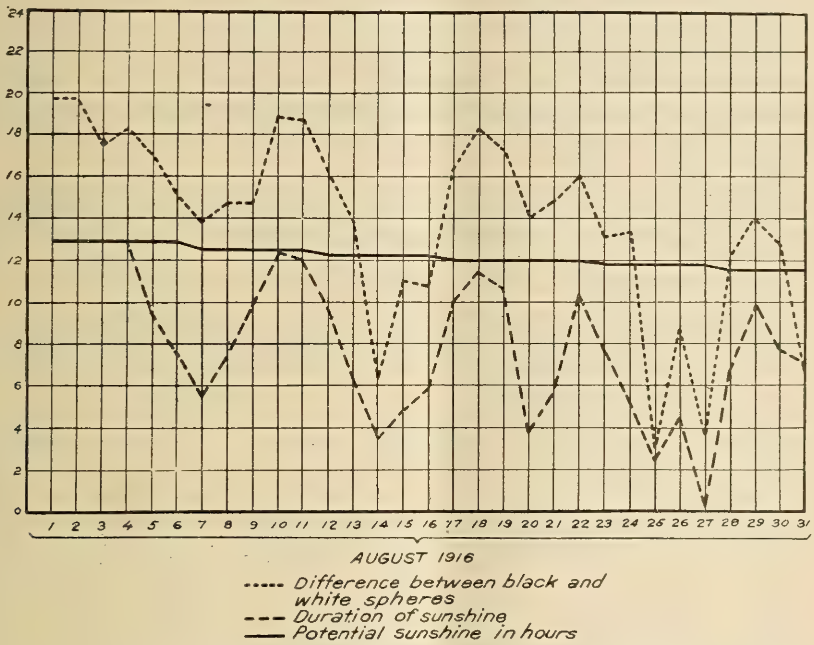

FIG. 10.—Difference between black and white spheres in evaporation as compared with hours of sunshine recorded by black bulb sunshine recorder.

Data on sunshine intensity were obtained by noting the difference in the evaporation between the radio-atmometer and the ordinary white porous cup atmometers.[1] The radio-atmometer used was a black sphere of the same size as the more common white form. Owing to its color it absorbs considerable of the radiant energy falling upon it, functioning in this regard much the same as foliage of ordinary plants. The white porous cup, on the other hand, absorbs comparatively little radiant energy and is therefore not appreciably affected by increased light intensity. Hence, while by night the evaporation from the radio-atmometer and from the white porous atmometer of the same size and form is practically identical, by day the black cup, on account of its higher temperature, shows a greater rate of evaporation. Therefore the difference in the evaporation from the radio or black atmometer and the white atmometer affords a rough estimate of varying intensities of sunlight for the different periods and type stations. The actual variation intensity, of course. bears an important relation to transpiration and photosynthesis.

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[1] Livingston, B. E. A radio-atmometer for comparing light intensity. Plant World, 14, No. 4: 96–99. 1911.

Only the duration of sunshine is measured by the Marvin sunshine instrument of the Weather Bureau pattern. Unless the investigator is working in the vicinity of an experiment station or similar base, the Marvin sunshine recorder can not, of course, be operated. The black and white porous cup atmometers, on the other hand, may be set up wherever desired. Accordingly, it is worth while to compare the sunshine records obtained from these two instruments. The data are given in Table 8 and are shown graphically in figure 10.

TABLE 8.—*Comparison of sunshine records obtained from a sunshine recorder of the Weather Bureau pattern, and the difference in evaporation between atmometers with black and white spheres. Readings taken in August, 1916.*

Date.	Difference between black and white spheres.	Duration of sunshine (Marvin sunshine recorder).	Possible sunshine.	Date.	Difference between black and white spheres.	Duration of sunshine (Marvin sunshine recorder).	Possible sunshine.
1916.	*cc.*	*Hours.*	*Hours.*	1916.	*cc.*	*Hours.*	*Hours.*
Aug. 1	19.6	12.9	12.9	Aug. 17	16.4	9.9	12.0
2	19.6	12.9	12.9	18	18.1	11.4	11.9
3	17.6	12.8	12.9	19	17.1	10.6	11.9
4	18.1	12.9	12.9	20	14.0	3.6	11.9
5	17.1	9.4	12.9	21	14.8	4.9	11.9
6	14.9	7.4	12.3	22	15.9	10.5	11.9
7	13.7	5.6	12.3	23	13.0	7.7	11.8
8	14.5	7.3	12.3	24	13.3	5.2	11.8
9	14.6	9.8	12.2	25	3.0	2.3	11.8
10	18.7	12.1	12.2	26	8.8	4.4	11.7
11	18.6	12.0	12.2	27	3.6	0.2	11.7
12	16.2	9.8	12.2	28	12.2	6.8	11.6
13	13.7	6.3	12.1	29	13.9	9.7	11.6
14	6.1	3.6	12.1	30	12.8	7.8	11.6
15	10.9	4.8	12.1	31	6.6	7.2	11.6
16	10.7	5.7	12.1				

In following the slope of the curves as shown in figure 10, an agreement of 67 per cent (20 periods out of 30) is found, and the disagreements in practically all cases are relatively slight. The most conspicuous differences in ordinate values occur for days when the sky is partly cloudy and the sunshine more or less intermittent. In such instances there is almost invariably a much greater fluctuation in the values of the atmometric sunlight index than in the values of sunshine duration as recorded by the Marvin recorder. This may be accounted for by the fact that the evaporation from the black surface atmometer responds more quickly to fluctuation in sunshine than does the mercury column of the sunshine recorder of the Weather Bureau type.

The data seem to warrant the statement that the use of atmometers in obtaining sunshine duration affords quite as reliable a record as does the more costly Marvin sunshine recorder. Of course, the impossibility of operating atmometers when the temperature drops below freezing makes them of value only during the growing season. Where it is desired merely to obtain a summary of the sunshine record, it is necessary to read the instruments only about twice per month, whereas the Marvin recorder must be read daily.

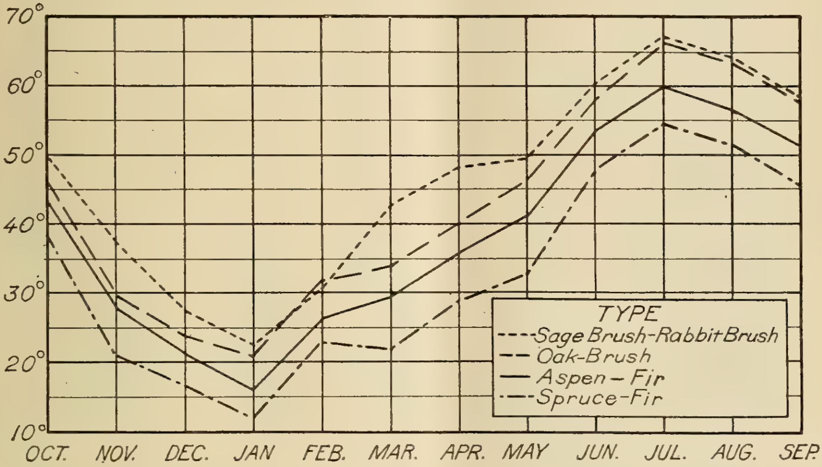


FIG. 11.—Monthly mean temperatures October, 1915–October, 1916.

COMPARISON OF THE CLIMATIC CHARACTERISTICS OF THE THREE PLANT TYPES.

TEMPERATURE.

For purposes of comparison there is probably no better way of showing differences in temperature in the type stations than to give the monthly mean temperature for each station. This is shown graphically in figure 11. Throughout the year the mean monthly temperature is appreciably lowest in the spruce-fir and highest in the sagebrush-rabbit-brush type. In general, the slopes of the mean-temperature curves of all the climatic types are similar, and this is especially true for the main growing season, from June to September, inclusive.

In the monthly range in temperature for the respective types there are even greater contrasts than in the daily means. The range in the monthly temperatures is shown in figure 12. These temperatures differ most notably from those given in figure 11, representing the monthly means, in (1) the similarity in vertical form and proximity

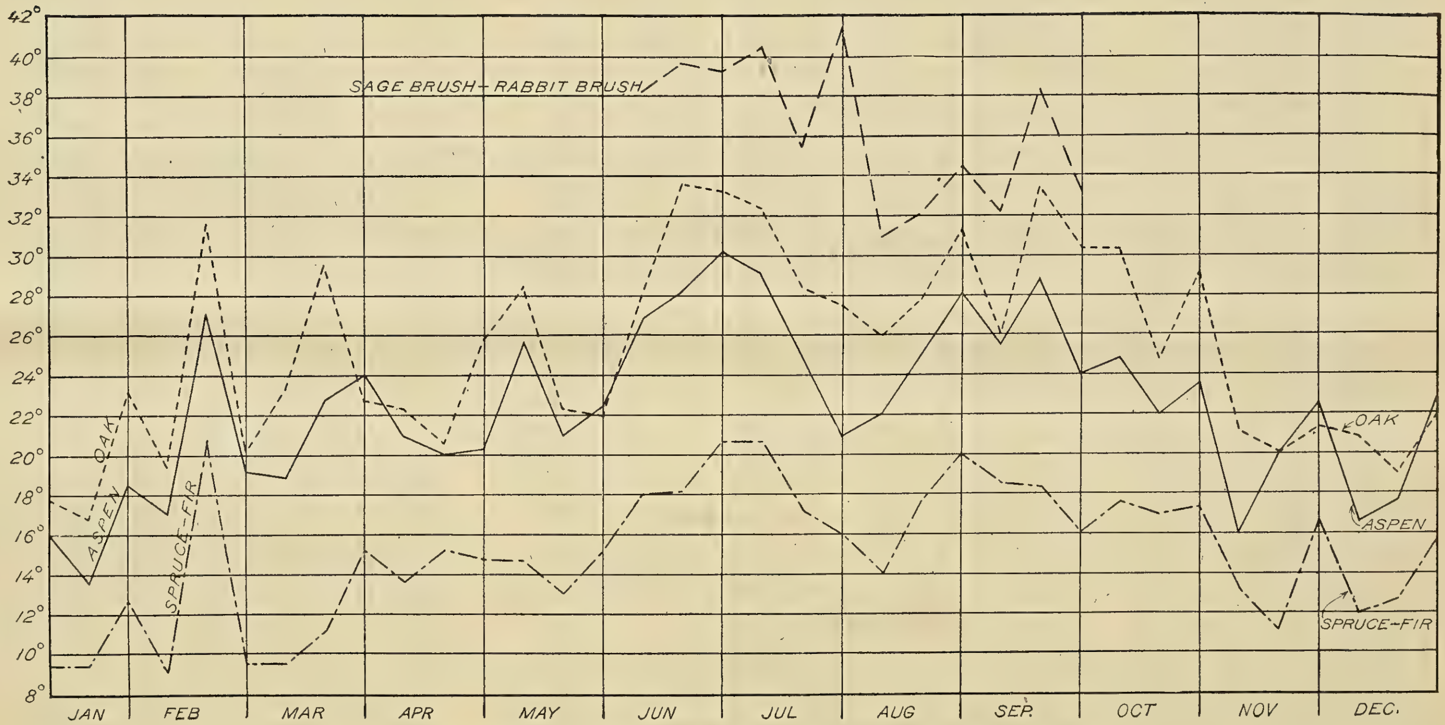


FIG. 12.—Range of temperatures in the four types January–December, 1916.

of the curves in the case of the oak-brush and the aspen-fir types, and (2) the decreased range or flattening of the curve in the spruce-fir type.

It is not possible by a review of the monthly mean temperatures to form a mental picture of the relative growing and nongrowing temperatures; that is, the temperatures above or below 40° F. These are summarized in Table 9 and graphically represented in figure 13.

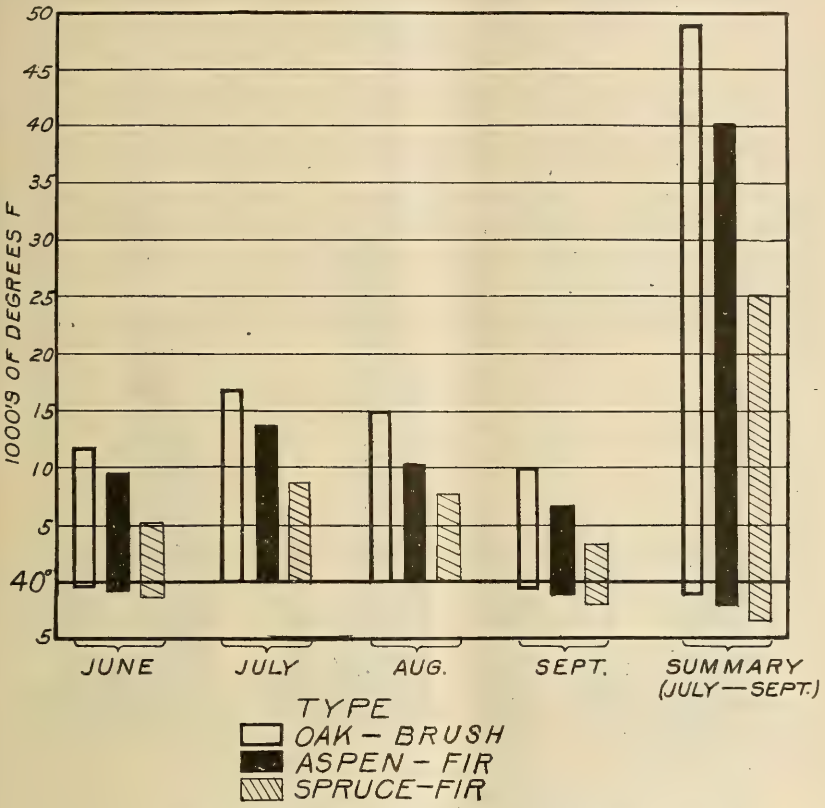
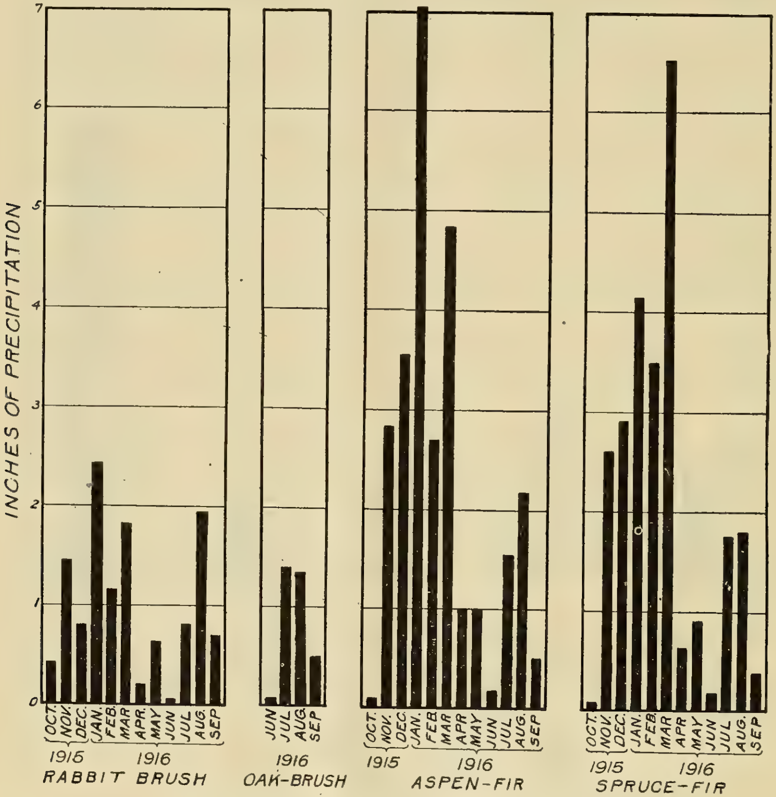


FIG. 13.—Summation of temperatures above and below 40° F., 1916.

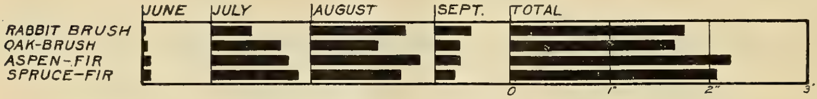
TABLE 9.—*Summary of temperatures above and below 40° F.*

Month.	Temperature segregations.	Oak-brush type.	Aspen-fir type.	Spruce-fir type.
		°F	*°F.*	*°F.*
June	above	11,400	9,347	5,090
	below	350	767	1,399
July	above	16,919	13,773	8,843
	below	15	42	73
August	above	14,929	10,357	7,874
	below	0	74	103
September	above	10,222	6,838	3,505
	below	640	1,034	1,786
Total	above	53,470	40,315	25,312
	below	1,005	1,917	3,361

The smallest number of heat units above 40° F. and the largest number below 40° F., as shown in figure 4, occur in June and September, near the beginning and ending of growth in the two lower types represented.[1] One of the most significant facts brought out in Table 9 is the absence of temperatures below 40° F. for August, in the oak-brush type. All types considered, July and August are the most favorable months for growth, in so far as it is determined by temperature.



MONTHLY AND ANNUAL PRECIPITATION



MONTHLY PRECIPITATION DURING GROWING SEASON 1916

FIG. 14.—Precipitation record, 1915–1916.

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[1] Growth begins in the oak-brush type approximately June 1. In the aspen-fir type the leaves begin to unfold about two weeks later. In the spruce-fir type growth begins between 3 and 4 weeks later than in the oak-brush type.

On the basis of the beginning of growth and the occurrence of killing frosts the growing periods in days for the respective types are approximately as follows:

Oak-brush type	120
Aspen-fir type	105
Spruce-fir type	70

PRECIPITATION.

The monthly precipitation from October, 1915, to September, 1916, is summarized in figure 14.

In view of the higher temperature, the longer growing season, and the higher evaporation in the oak-brush type, it is significant that the annual precipitation is less in that type than in any of the more elevated types in which plant studies were conducted. The annual averages of precipitation of the types, including the untimbered type below the oak-brush, as recorded from 1914 to 1916, inclusive, are:

	Inches.
Sagebrush-rabbit-brush type	11.15
Oak-brush type	13.25
Aspen-fir	27.18
Spruce-fir	25.40

During the growing period in 1916 the aspen-fir type, as in the case of the three-year average, received the heaviest precipitation, nearly the same amount, however, being recorded in the type immediately above.

EVAPORATION.

Monthly evaporation and precipitation are represented in the same figure (fig. 15). Owing to the occurrence of freezing temperatures in June, particularly in the two higher types, unbroken evaporation records were obtained only from July to September, inclusive.

Figure 15, based upon the records of the porous cup atmometer (see fig. 16), shows that the highest evaporation occurs each month in the oak-brush type. In the spruce-fir type the evaporation is nearly as great as in the lowest association, while in the aspen-fir type it is much less than in either of the others. Table 7 and figure 8 also indicate that the evaporation in the oak-brush and spruce-fir types is much greater than in the aspen-fir type.

In the case of growth studies begun in the stations at a later period, the summation of evaporation is quite as contrasted, as is shown in figure 9. While the records in this series of experiments cover a shorter period than those in the original study, being 52, 70, and 65 days in the oak-brush, aspen-fir, and spruce-fir types, respectively, evaporation was notably greater in the lowest type, least in the central, and intermediate in the highest.

The high evaporation in the oak-brush type is due chiefly to high temperatures and low relative humidity. In the spruce-fir type the high evaporation is accounted for chiefly by the high wind velocity, as will be shown later. Owing to the aspen-fir type being intermediate in elevation between the other two, and having a notably heavier stand of vegetation, especially tree growth, the factors influencing evaporation are in no instance extreme.

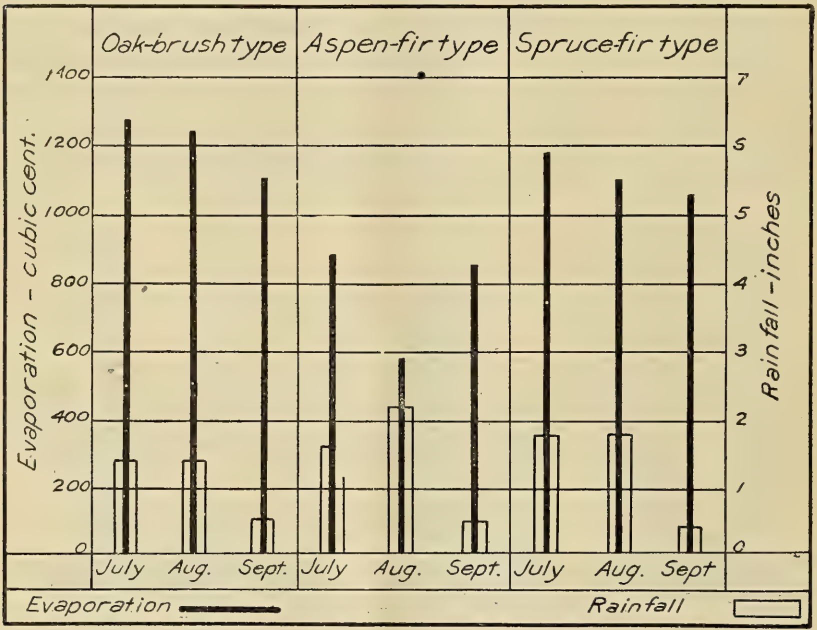

FIG. 15.—Monthly evaporation from spherical atmometers and corresponding precipitation in type stations, 1916.

WIND VELOCITY.

Largely because of the physiographical features, the velocity of the wind is notably greater in the spruce-fir type than in the lower associations. The comparative intensity of this factor may be appreciated readily by summing the daily wind movement by monthly periods. Since the wind velocity during the growing season is probably an influential factor in the development of the vegetation, data are presented in Table 10 showing the wind movement during the growing seasons of 1915 and 1916.

TABLE 10.—*Monthly wind movement in the spruce-fir and in the aspen-fir type station.*

Month.	Year.	Aspen-fir.	Spruce-fir.
		Miles.	*Miles.*
June	1915	3,081	6,501
	1916	3,020	7,119
July	1915	3,055	6,807
	1916	3,697	5,505
August	1915	3,339	4,836
	1916	3,198	5,116
September	1915	3,008	7,632
	1916	3,080	6,873
Total	1915	12,483	25,776
	1916	12,995	24,613

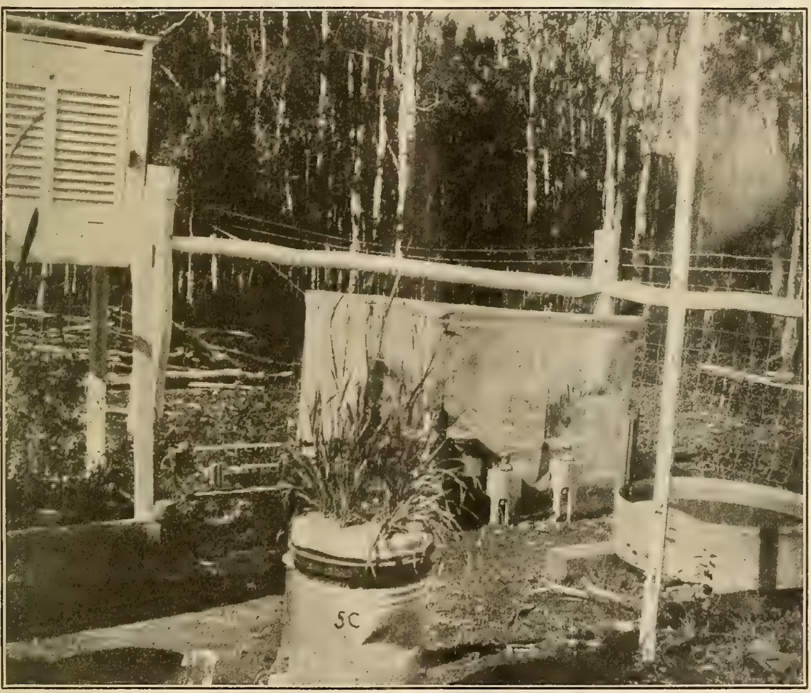

FIG. 16.—View of atmometers and evaporating pan used in measuring the evaporating power of the air.

The above figures show that the wind movement during the growing seasons of 1915 and 1916 was greater by approximately 100 per cent in the heart of the spruce-fir type than in the aspen-fir association 1,300 feet lower. In summarizing the wind movement by 10-day periods the velocity is found to exceed by 200 per cent that in the aspen-fir type for certain periods. Obviously, the gales over the elevated, sparsely vegetated plateaus have a profound effect on the evaporation and to some extent at least on the transpiration rate of the vegetation.

SUNSHINE.

In recording the sunshine it was deemed advisable to note both the possible and the actual duration, since both are important to the development of vegetation. These factors are graphically shown in figure 17 for the aspen-fir type during the seasons of growth in 1915 and 1916.

In 1915 the greatest actual sunshine occurred in July, while in 1916 it was recorded in June. Owing partly to the advancement in the season but chiefly to the topographic features adjacent to the meteorological stations, there is a gradual decline in the potential sunshine duration throughout the growing season. The potential and actual sunshine durations, on the basis of three seasons' records, are found to be practically identical in the three associations studied; consequently, no attempt is made to correlate sunshine duration with the plant activities.

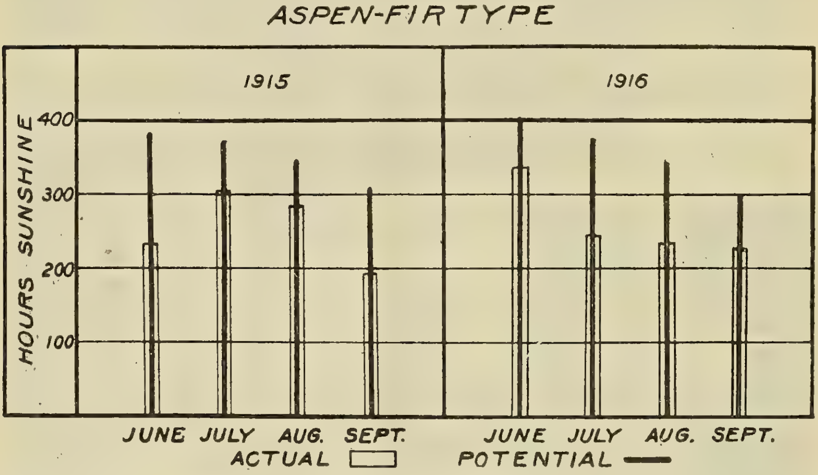

Fig. 17.—Actual and potential sunshine during growing season in the aspen-fir type, 1915.

BAROMETRIC PRESSURE.

So far no direct fundamental relations have been established between barometric pressure and the development of the plant.[1]

The relation of high and low pressure to local rainstorms and high winds was observed in the aspen-fir association throughout the growing season of 1916, and the results are shown in figure 18.

Practically always when the pressure dropped appreciably below normal a change followed in the weather. While the amount of precipitation and the movement of the wind are not necessarily pro-

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[1] Zon, Raphael, Meteorological observations in connection with botanical geography, agriculture, and forestry. Monthly Weather Review, April, 42: 217–23. 1914.

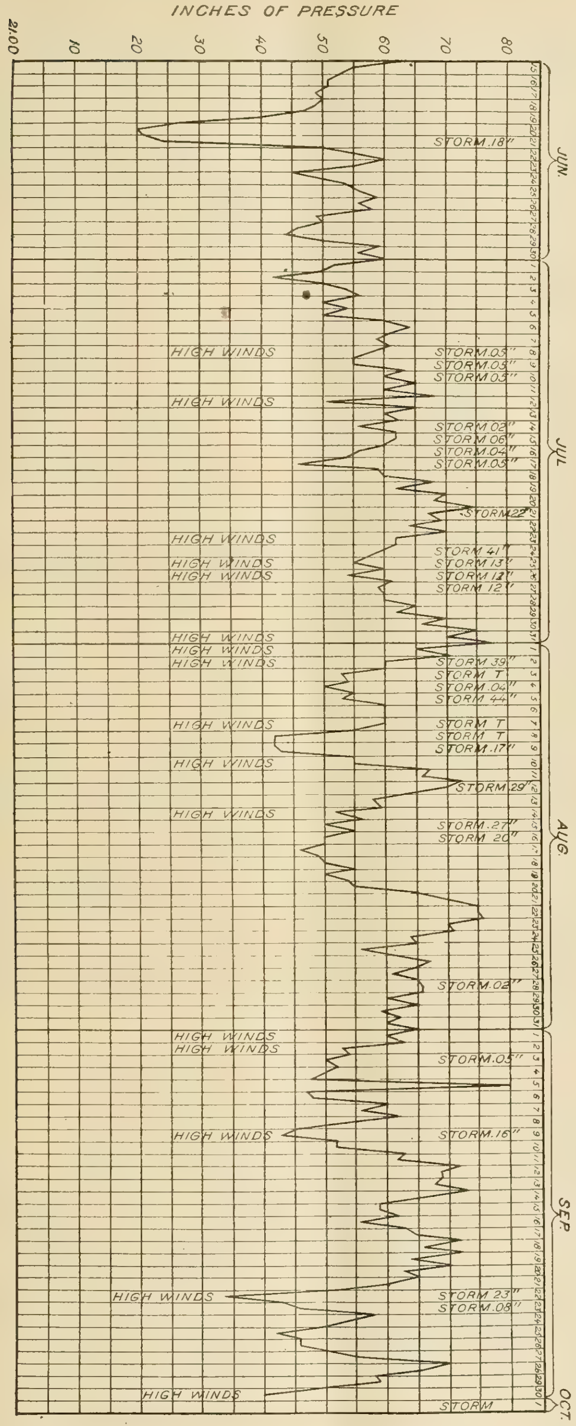

Fig. 18.—Barometric pressure and its relation to storms, 1916.

portional to the pressure below normal, figure 18 indicates that local observations of pressure are of some value in forecasting changes in the weather conditions where the daily weather map is not available. As stated, however, the relation of pressure to vegetative activities can best be expressed by the summation of certain other factors correlated with pressure and known to exert a direct influence on the development of the plant.

SUMMARY OF CLIMATIC COMPARISONS.

The climatic characteristics of the plant-type zone may be summed up as follows: The mean annual temperature is highest in the least elevated type zone and decreases gradually with the increase in altitude until, in the spruce-fir association, the season of growth covers a period of only 70 days. In the oak-brush type zone the growing season is approximately 120 days. Precipitation, on the other hand, is normally only about half as heavy in the oak-brush type as in the type zones above. In general, however, the precipitation is somewhat heavier in the aspen-fir than in the spruce-fir type zone. The precipitation is rather uniformly distributed throughout the year. The evaporation is highest in the oak-brush type, where the greatest heat units and least rainfall are recorded. The evaporation factor is nearly as intensive in the spruce-fir type, however, while in the aspen-fir association it is only about half as great. The strong evaporation in the spruce-fir type is accounted for by the high wind velocity, which often exceeds 40 miles per hour for several hours in succession. The seasonal wind movement in the spruce-fir type is approximately 100 per cent greater than in the associations below. The possible and actual sunshine are found to be practically identical in the respective types. The barometric pressure, of course, varies with the elevation, but the seasonal fluctuations in a given locality are slight and insignificant so far as concerns any direct effect on the vegetation.

TEMPERATURE SUMMATIONS.

Owing to the mass of climatic data compiled, it was necessary to simplify them by summarizing[1] on different bases.

The temperature factor in the respective stations for the periods during which the plants were under observation was summarized in three ways: (1) By physiological temperature coefficients as developed by Lehenbauer[2] and later applied by Livingston;[3] (2) the sum of the positive or effective temperatures, that is, the sum of the means above 40° F., as originally proposed by Merriam,[1] and (3) the sum of the daily mean temperatures. For comparison with plant growth in this study, the sum of the temperature efficiencies for the growth periods has been used instead of the average temperature efficiency. This was done for the reason that the plant measurements represent total growth for the respective periods.

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[1] The literature relative to methods of comparative summations of climate has been reviewed by Abbe, Cleveland, First report on the relation between climate and crops. U. S. Weather Bureau Bull. 36, 1905.

[2] Lehenbauer, P. A. Growth of maize seedlings in relation to temperature. Physiol. Res. 1: 247–288. 1914.

[3] Livingston, Burton E. Physiological temperature indices for the study of plant growth in relation to climatic conditions. Physiol. Res. 1: 399–420. 1916.

Physiological temperature coefficients are based upon data obtained by Lehenbauer in the study of the elongation of the shoots of maize sprouts when exposed to practically constant temperature for 12-hour periods. These 12-hour exposures were made degree by degree at temperatures ranging from the minimum at which growth takes place, through the optimum, and on to the maximum temperature at which growth is possible. Varying increments of elongation naturally took place according to the temperature to which the sprouts were exposed; and these growth rates were platted against the temperature used, giving a curve showing the relation between temperature and the rate of growth of the plant. The lengths of the ordinates of this growth curve furnish a series of numbers which represent the efficiency of the various temperatures in promoting the growth of maize. The application of the physiological temperature coefficient to any plant other than the one used by Lehenbauer is based on the assumption that the general relation of growth and temperature is the same as for the maize. Whether or not the physiological temperature indices obtained under controlled conditions will apply to field plants where the temperatures fluctuate widely can not be stated. It may be presumed for the present, however, that they will more closely account for physiological responses of field plants than will direct temperature summations.

Since these indices are based on physical and chemical processes taking place within the plant, temperatures at which no appreciable activities take place are at once eliminated; at the same time the efficiency of the temperature up and down the thermometer scale receives the proper weight.

In applying this method of temperature summation the daily mean temperatures were first obtained from the hourly corrected thermometer readings for the period during which the plants in the type stations were grown. The corresponding physiological indices were then substituted for the daily means and these indices summed for the period in question.

By positive or effective temperatures is meant the number of degrees of temperature above the minimum at which growth can take place. On the basis of many plants studied this minimum may be placed at approximately 40° F. Hence in the periodic and seasonal temperature summations, the daily mean temperature less 40, the uneffective growing temperature, were added. These summations of effective temperatures were made, in the case of each of the type stations, for the period *in toto* during which the plants were grown, as well as for shorter periods. This method involves a slight error, since in a few instances during the growing season the mean dropped below 40°; but the error thus introduced is so small as to be quite negligible.

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[1] Merriam, C. Hart. Life zones and crop zones in the United States. U. S. Department of Agriculture Bull. 10: 55–73. 1898.

The sum of the daily mean temperatures was obtained from the hourly corrected thermograph readings and added according to definite periods. These summations are presented chiefly for purposes of comparison with the other two methods of summation described.

The temperature summations by the three methods are given in Table 11, in Section A, of the table for the plants that were started June 13 and grown until killing frosts arrested their activities, and in Section B, for those started several weeks later and grown until inclement weather set in.

TABLE 11.—*Temperature summations, in degrees Fahrenheit, for period of growth of potometered plants in type stations.*

SECTION A.[1]

Type.	Duration of period.	Sum of daily mean.	Sum of positive temperature.	Sum of physiological temperature efficiency.
	Days.	*°F.*	*°F.*	*Index.*
Oak-brush	81	5,034	1,789	2,473.7
Aspen-fir	95	5,445	1,404	1,560.6
Spruce-fir	91	4,631	991	730.5

SECTION B.

Type.	Duration of period.	Sum of daily mean.	Sum of positive temperature.	Sum of physiological temperature efficiency.
Oak-brush	52	4,330	1,528	1,938.2
Aspen-fir	70	3,932	1,132	1,025.8
Spruce-fir	65	3,285	685	486.1

[1] Section A of the table has reference to fig. 19, and Section B to fig. 20.

It should be pointed out that the temperature summations in the case of the oak-brush type are for a period of 81 days, which marks approximately the time required for the maturity of the plants. The summations in the aspen-fir and spruce-fir associations are for 95 and 91 days, respectively. Owing to the relatively low temperatures the plants in the two latter types did not reach maturity, killing frosts having occurred early in September. From the temperature summations in figure 19, therefore, it should be understood that the

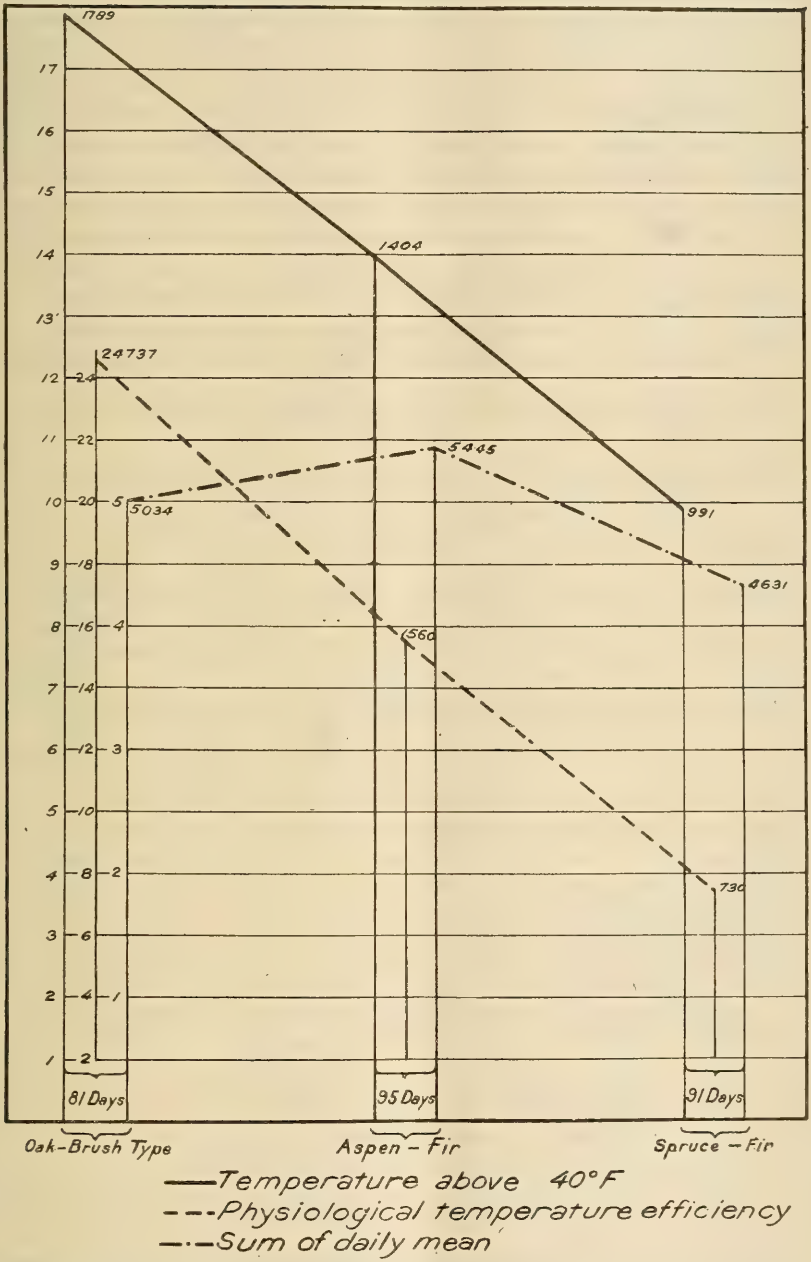

FIG. 19.—Temperature efficiency summations for period of growth of plants used in main experiment.

data given for each station represent slightly different numbers of days. In figure 19, as well as in certain other graphs, the curves are comparable in each case as to direction of slope; but it should be understood that the lengths of the ordinates are not in all cases directly comparable; the vertical scales employed are merely convenient ones and are quite arbitrary.

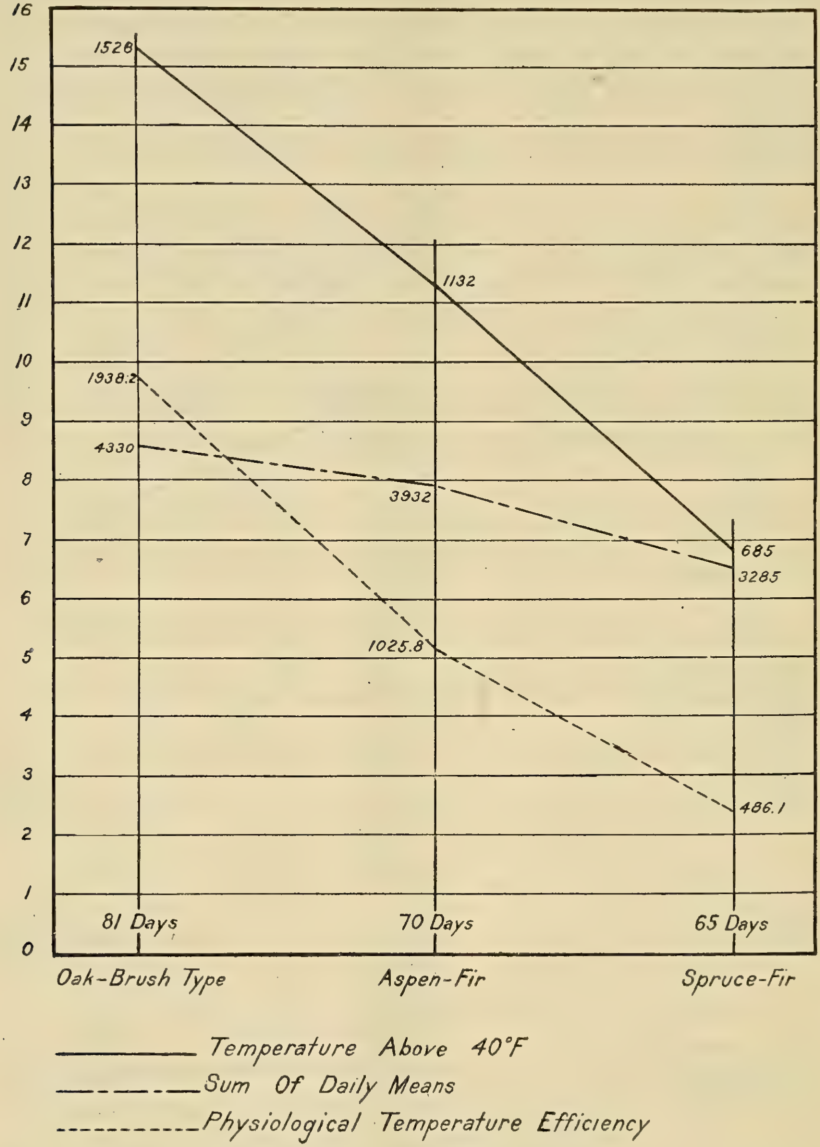

FIG. 20.—Temperature efficiency summations for period of growth of special experiments.

It is a noteworthy fact that the summed physiological temperature coefficients and the sum of the positive temperatures; that is, those above 40° F., bear practically the same relation to each other in the respective type stations. This has also been observed to hold true, in general, for shorter periods (fig. 20). Neither of these summations, however, agrees with the sum of the daily temperatures. As will be shown elsewhere, both the physiological temperature coefficients and the sum of the positive temperatures show some relation to growth and other plant activities. This does not appear to hold true of the summation of the daily mean temperature. Because of the corresponding slopes of the graph in figure 19 between the physiological temperature summation and the sum of the positive temperatures, either may be used for comparison with the plant-growth data in the case of the batteries observed for the period in question.

CORRELATION BETWEEN GROWTH AND ENVIRONMENTAL FACTORS.

RELATIVE DEVELOPMENT OF THE PLANTS IN THE TYPE STATIONS, AND THE CORRESPONDING WATER REQUIREMENTS.

A summation of the data obtained for the development and water requirements in the different type stations of wheat, peas, and brome grass (based on dry weight of tops) is given in Table 12. These figures represent the activities of the plants for 81 days in the oak-brush type, 95 days in the aspen-fir type, and 91 days in the spruce-fir type. The temperature indices and evaporation summaries for the respective periods are given in figures 19 and 8.

TABLE 12.—*Summation of growth and water requirements of plants developed in the type stations.*

Type.	Plant.	Average stem height of peas and leaf length of wheat and brome grass.	Number of leaves.	Water requirement per unit dry matter.
		Mm.		*Grams.*
Oak-brush	Wheat	3,990	28	626
	Peas	4,781	206	779
	Brome grass	15,980	125	803
Aspen-fir	Wheat	8,560	53	288
	Peas	11,863	398	368
	Brome grass	22,290	144	516
Spruce-fir	Wheat	5,280	26	300
	Peas	5,584	166	345
	Brome grass	8,114	81	756

The values given in Table 12 are platted in figures 21, 22, and 23. The most striking features brought out in the graphs are (1) the greater vegetative development, including number of leaves, leaf length, and stem height, in the aspen-fir association, and (2) the relatively high water requirement for the production of a unit of dry matter in the oak-brush type.

In the case of peas, the number of leaves produced in the aspen-fir type, as compared with the oak-brush and spruce-fir types, respectively, is approximately in the ratio of 4, 2, and 1.7. The leaf length of wheat shows a ratio of about 2, 1, and 1.3 in favor of the aspen-fir association. In the case of the brome grass practically the same relations exist.

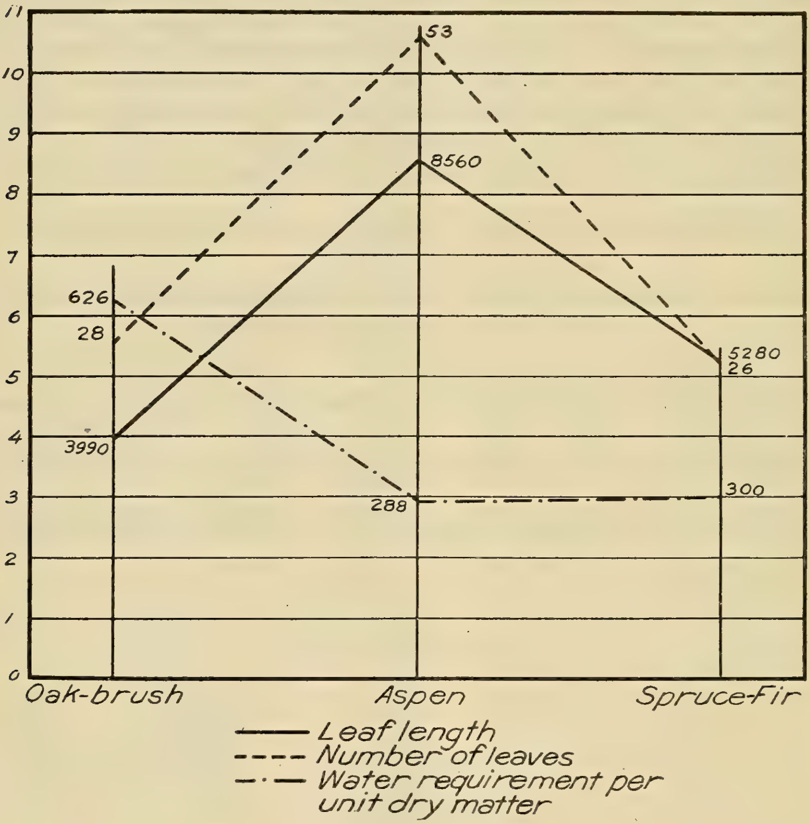

FIG. 21.—Water requirements and vegetative growth of wheat in the three climatic types.

In each instance the water requirement per unit of dry matter is the highest in the oak-brush type. The fact that the plants were grown for a longer period in the highest and middle stations would naturally imply that they used more total water, but not necessarily that they had a higher water requirement per unit of dry weight. A comparison shows that in the case of wheat and peas the water requirements are very nearly the same in the central and in the highest types, while brome grass shows a greater demand for water in the spruce-fir type than in the aspen-fir type. All three species exhibit a markedly interesting relation of development to water requirement, namely, that the lowest water requirement for the production of a unit of dry matter is invariably associated with the most luxuriant growth. Further, figure 8 shows that the evaporation curve, corresponding to the period of growth of the plants, slants in the opposite direction from those of the development of the plants as platted in figures 21, 22, and 23. In the oak-brush type, where the water requirement is highest, evaporation is most intensive.

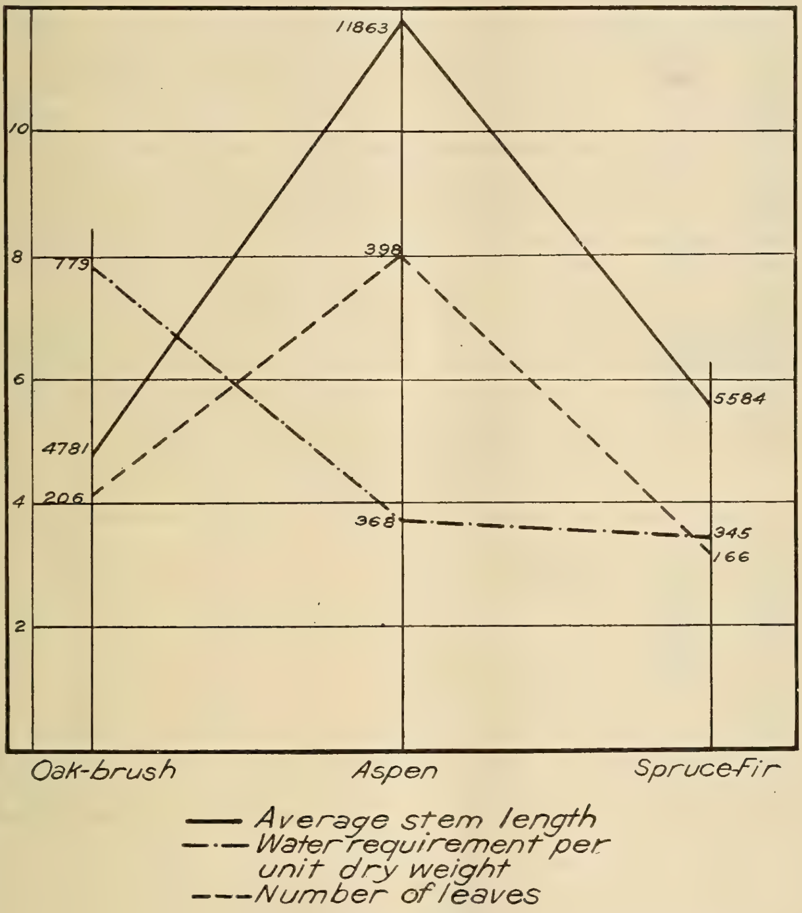

FIG. 22.—Water requirements and vegetative growth of Canada field peas in the three climatic types.

The data on the relative development of the plants in the type stations and the corresponding water requirements are especially important, since they represent vegetative activities throughout the season. Hence these data appear to throw some light on the causes of failure or success of experimental trials with plants in the types represented.

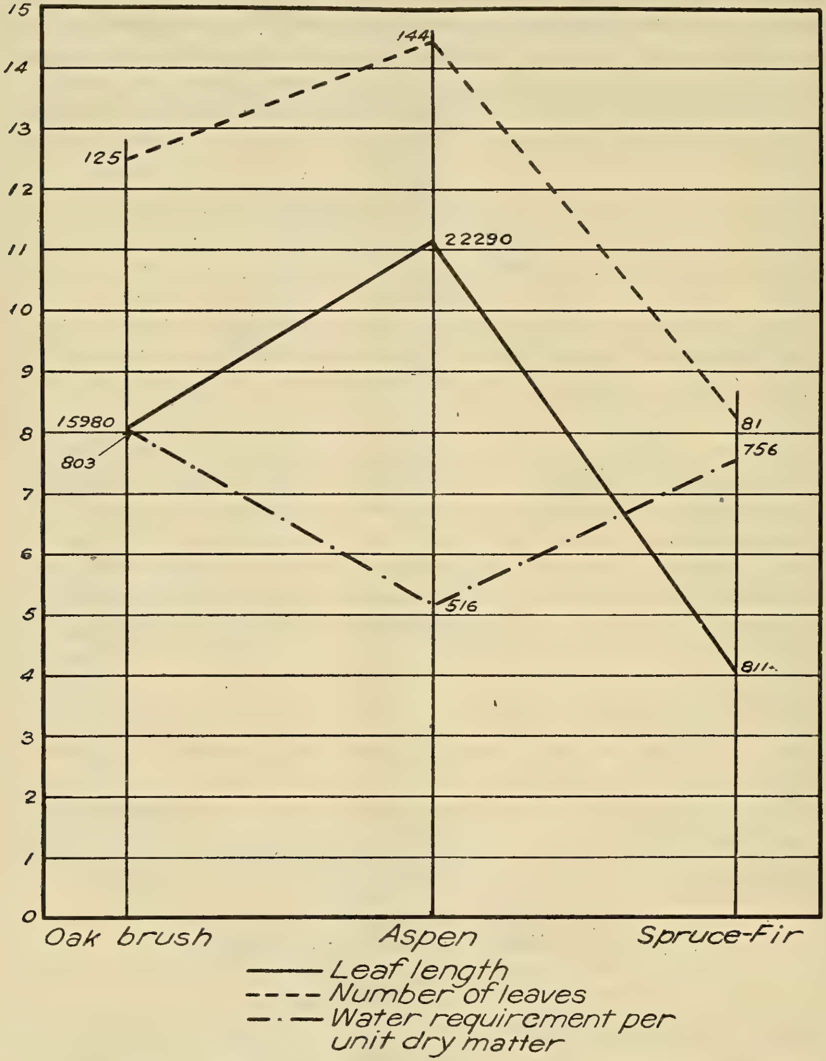

FIG. 23.—Water requirements and vegetative growth of brome grass in the three climatic types.

THE EFFECT ON PLANT GROWTH OF DIFFERENCES IN THE AMOUNT OF HEAT AVAILABLE IN THE THREE TYPES.

EFFECT OF TEMPERATURE AS INDICATED BY DIFFERENCES IN WATER REQUIREMENTS BASED UPON STAGE OF DEVELOPMENT AND CONDITION OF CERTAIN AERIAL PARTS.

The total effective heat units and length of growing season in the types studied are such that only in the lowest type do the plants reach full maturity.[1] In the case of Experimental Series No. 1, in which the standard plants were started simultaneously in all types as soon as the temperature favored growth in the highest type, wheat heads filled well in the aspen-fir type but killing frosts occurred before the caryopsis hardened thoroughly; in the type above, growth was arrested when the heads were still in a developmental stage. Records of these plant specimens, supplemented by those of the late planted batteries (Experimental Series No. 2) afforded data as to the relative water requirements of plants in different stages of development. Because of the difference in age of the plants in the early planted and later planted batteries, the two sets of specimens were really subjected to different environmental conditions, for it is well known that the same weather factors do not affect plants in different stages of development in the same way. For this reason the water requirements of the two sets of plants may not be entirely comparable.

For the purpose of comparisons between the water requirements of the entire tops of wheat and brome-grass specimens, heads included, and tops without the heads, the dry matter of the specimens with and without heads was recorded and the water requirements of each determined. The results are summarized in Table 13.

TABLE 13.—*Relation of water requirements of wheat and brome grass to effective temperatures in climatic types.*

WHEAT (EXPERIMENTAL SERIES No. 1).

Types.	Water requirement per unit dry weight.		Per cent of difference between water requirements without heads and with heads.	Temperature summation above 40° F.
	Without heads.	Including heads.		
	Grams.	*Grams.*		*Degrees.*
Oak-brush	857	626	37	1,789
Aspen-fir	358	288	24	1,404
Spruce-fir	355	300	18	991

WHEAT (EXPERIMENTAL SERIES NO. 2).

Types.	Without heads.	Including heads.	Per cent of difference	Temperature summation
Oak-brush	600	504	19	1,528
Aspen-fir	407	354	15	1,132
Spruce-fir	391	391	00	685

BROME GRASS (EXPERIMENTAL SERIES No. 1).

Types.	Without heads.	Including heads.	Per cent of difference	Temperature summation
Oak-brush	1,303	803	62	1,789
Aspen-fir	736	516	43	1,404
Spruce-fir	853	756	14	991

The above values, platted in figures 24, 25, and 26, exhibit a gradual falling off from the lowest to the highest station in the ratio

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[1] Owing to the early maturing qualities of mountain brome grass, this species more nearly reached maturity in all types than did the cultivated plants.

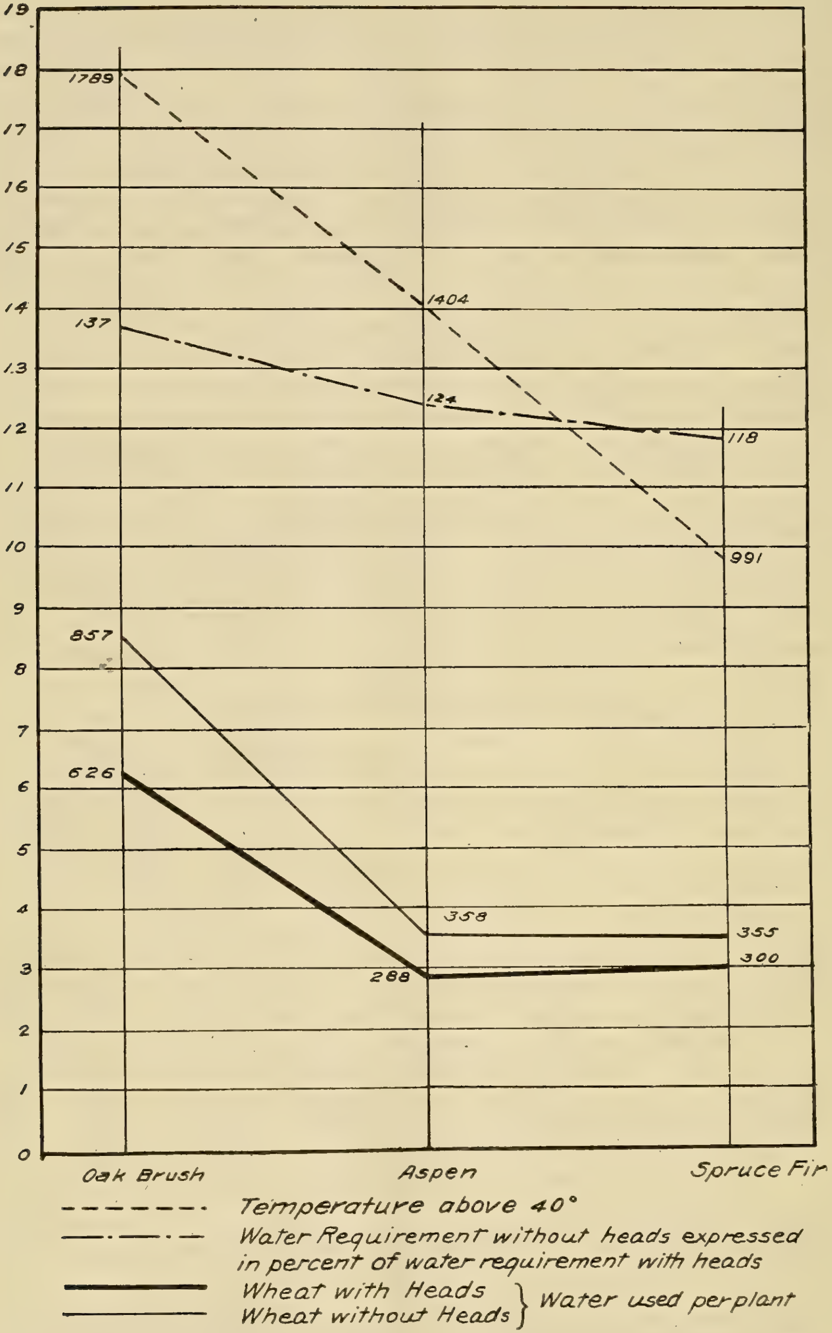

FIG. 24.—Water requirement of wheat based on weight of plant including heads, compared with water requirement based on weight without heads. (Experimental Series No. 1.)

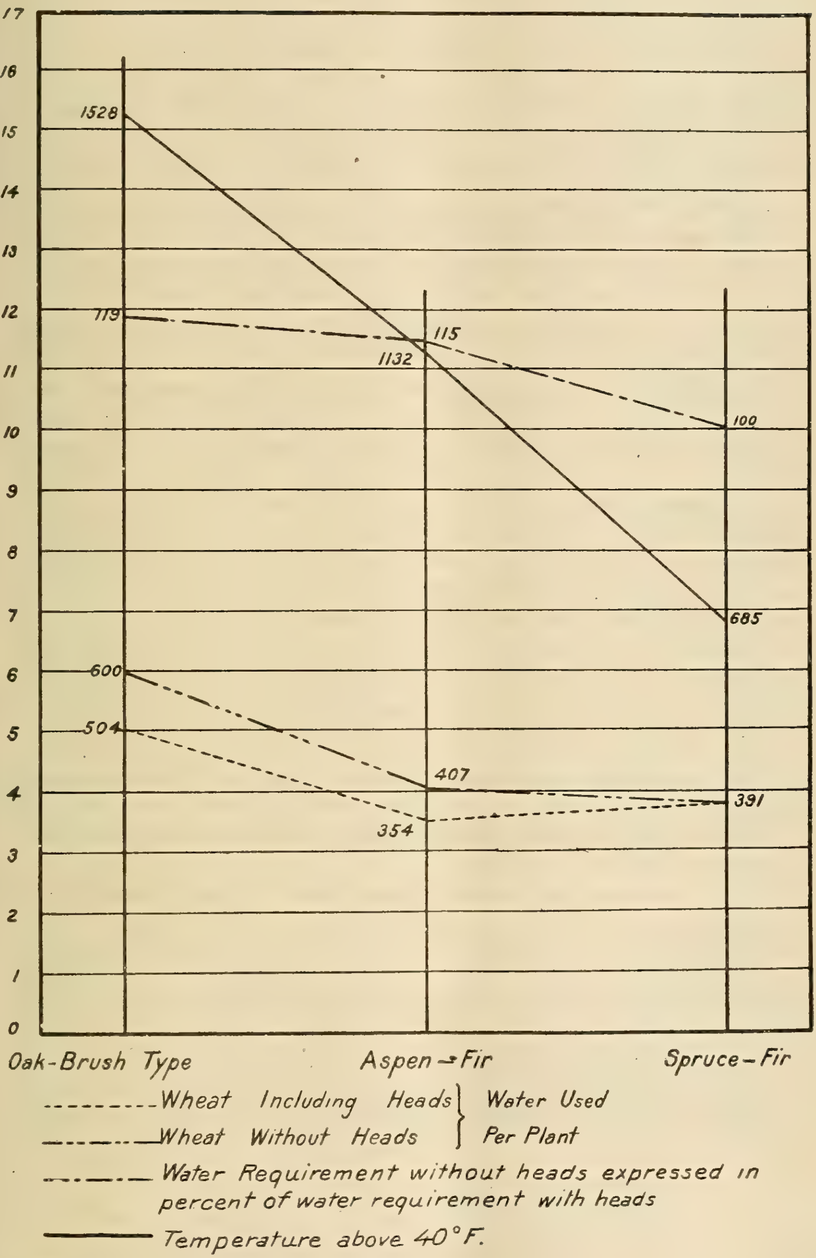

FIG. 25.—Water requirement of wheat based on weight of plant including heads, compared with water requirement based on weight without heads. (Experimental Series No. 2.)

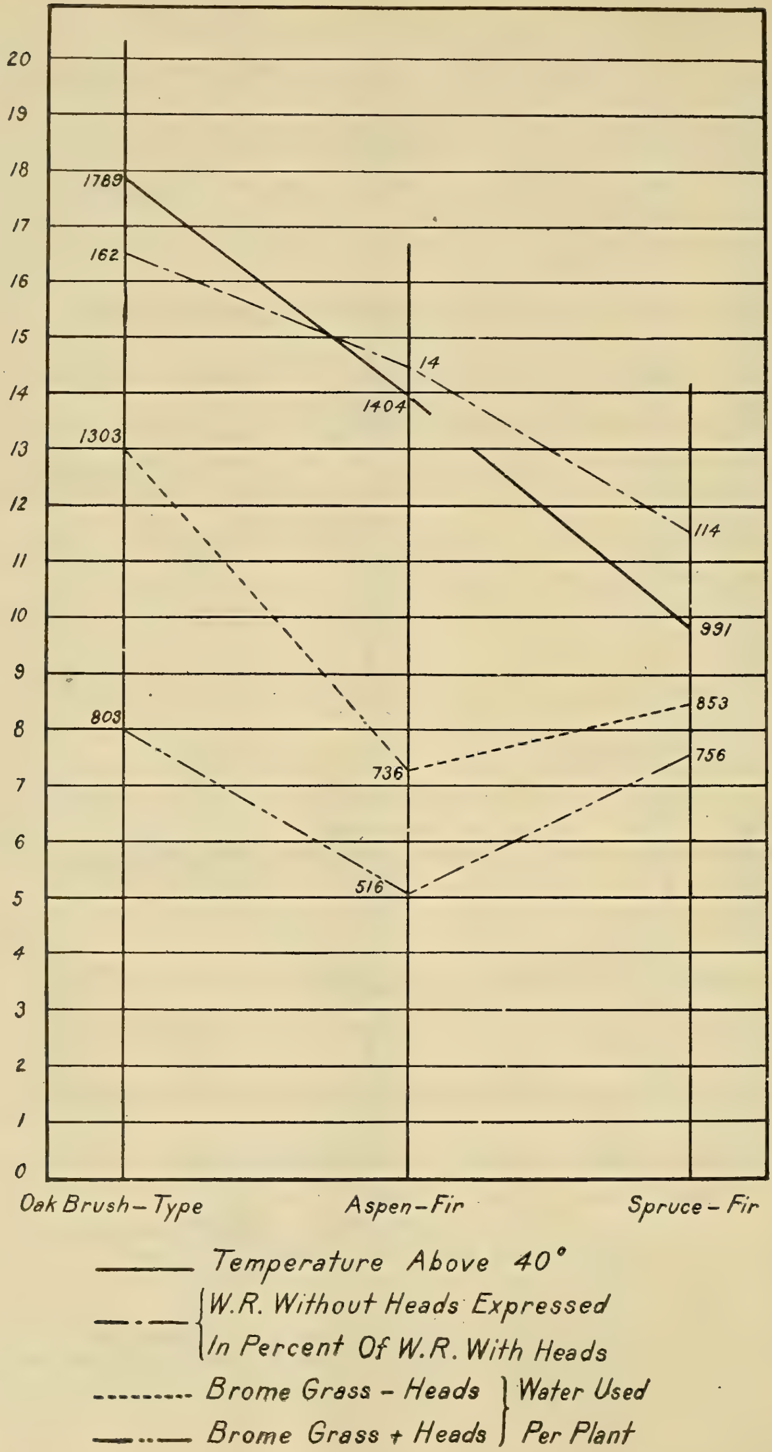

FIG. 26.—Water requirement of brome grass based on dry matter of plant including heads as compared with water requirement based on dry matter without heads

of the water requirements of wheat and brome grass without heads to those with heads. The difference is rather pronounced. In the case of wheat in the oak-brush type (fig. 24) it is 37 per cent, in the aspen-fir association 24 per cent, and in the spruce-fir type 18 per cent. In the case of less mature wheat specimens (fig. 25) the differences between water requirement of the plants without heads and those plants with heads is 19 per cent, 15 per cent, and zero; for brome grass (fig. 26) it is 62 per cent, 43 per cent, and 14 per cent.

The differences in the water requirement figures serve to show one of the responses of the plants to the different amounts of heat available in the three associations. In the oak-brush type, where the number of heat units is greatest, the plants are matured or nearly so, and a large proportion of the total dry matter of the plants is deposited in the seed heads. At the middle and upper stations, where the summed seasonal temperature efficiency is lower, the plants are less mature, and a correspondingly lower proportion of the total dry matter of the plants is deposited in the heads. This difference in the stage of maturity would seem, then, to account for the difference in the water requirements of the plant with heads and without heads, and the difference itself affords an approximate measure of the relative development and maturity of the plants in the different types.

It is noteworthy that in the figures representing the ratio of the water requirements of the plants based on (1) the tops, including heads and (2) the tops without heads (figs. 24, 25, and 26) the curves in each case fall, from the lowest to the highest type, in a manner roughly proportional to the fall in the temperature summations. This agreement in slope shows that the plants mature more slowly as the number of effective temperature units decreases.

EFFECT OF TEMPERATURE AS INDICATED BY PERIOD REQUIRED FOR PRODUCTION OF FLOWERS.

Additional data showing the relation of the development of the plant to temperature were obtained by noting the number of days required for the first appearance of flowers in the species grown in the type stations. In each instance temperature summations and average mean temperatures were recorded for each period, the results of which are summarized in Table 14.

TABLE 14.—*Periods required for the production of flowers in the vegetative types and temperature summations and average mean temperatures for the respective periods.*

Type station.	Peas.			Wheat.			Brome grass.		
	Days for appearnace of blossom.	Temperature.		Days for appearance of heads.	Temperature.		Days for appearance of heads.	Temperature.	
		Above 40° F.	Average daily mean.		Above 40° F.	Average daily mean.		Above 40° F.	Average daily mean.
		° *F.*	° *F.*		° *F.*	° *F.*		° *F.*	° *F.*
Oak-brush	43	1,007	64	40	915	69.2	39	785	60
Aspen-fir	64	988	56	52	785	55.2	52	685	58
Spruce-fir	88	980	51	71	847	52.0	63	660	52

Figures 27, 28, and 29 platted from Table 14 show a rather pronounced parallelism in the different figures in the trend of the curves from the lowest to the highest station representing the number of days required for the flowering of the species, on the one hand, and in the curves representing the number of heat units up to time of the production of flowers, on the other. Provided no other factor was operative in holding back growth in the case of the plants in question it would appear that temperature was the controlling factor in this instance. In the case of peas, flowers appeared 21 days earlier in the oak-brush type than in the aspen-fir type and 45 days earlier than in the spruce-fir type, the period between planting and flowering in the spruce-fir type being more than twice as long as the corresponding period in the oak-brush type. Wheat spikes appeared in the lowest type in 40 days; while in the central and highest types they began to show 12 and 31 days later, respectively. In the case of mountain brome grass, panicles showed in 39 days in the lowest type; but in the central station they did not begin to show until 13 days later and in the spruce-fir type 24 days later. One of the most interesting facts brought out in these observations is that in spite of the fewer days required for flowering in the oak-brush type a great many more flowers were produced than in the other types. In the case of wheat, for example, 40 per cent more heads appeared in the oak-brush than in the aspen-fir type, and over 100 per cent more than in the highest type.

The fact that there is very little slope in the effective temperature summation curves and in the average daily mean temperature curves in figures 27, 28, and 29 shows that practically the same number of heat units were required in each type for the production of flowers. On the physiological basis of temperature summation for the entire season, as has previously been pointed out, there were notably more heat units in the lowest type. The lowest temperature efficiency was recorded in the spruce-fir type, while in the central type the physiological temperature efficiency was intermediate. Since a habitat with low-growing temperatures requires a greater number of days for the plant to reach a given stage of maturity than a warmer situation, it is evident that the physiological temperature indices would be in inverse ratio to the time required to bring the plant to a given stage of maturity.

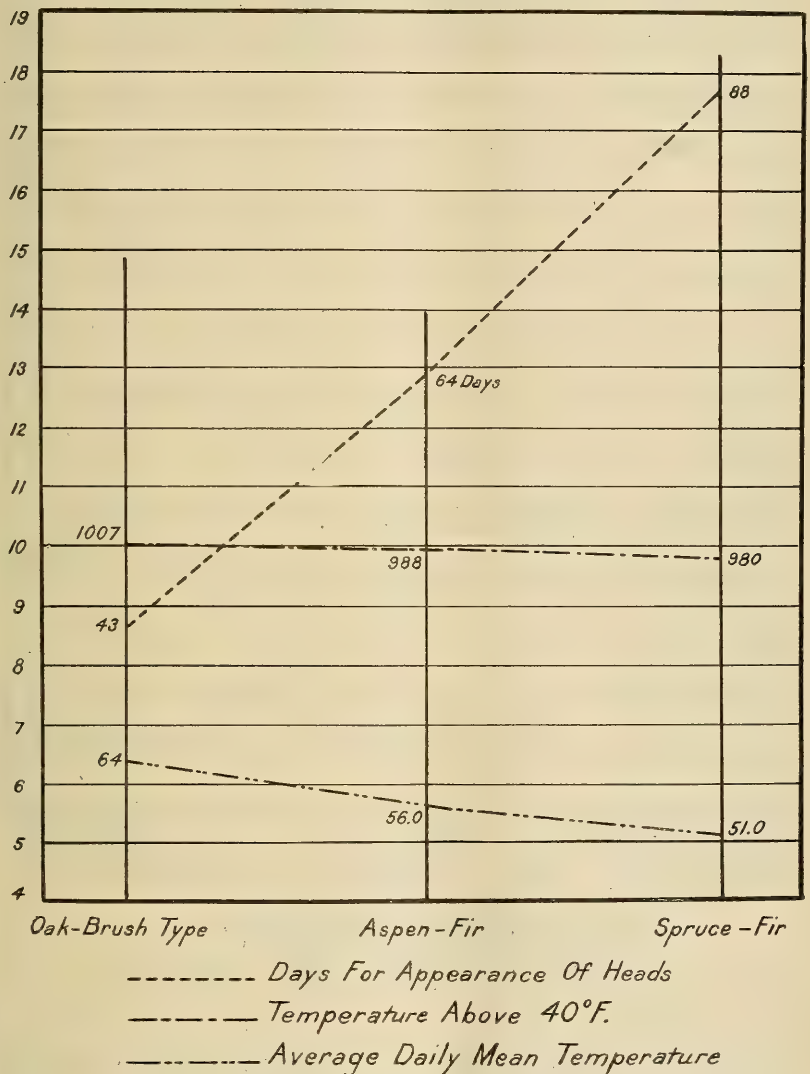

FIG. 27.—Relation of temperature to time of first appearance of blossoms in peas.

The difference in the time for the plants to reach approximately the same stage of maturity in the type stations may account, in part at least, for the difference in the character and composition of the vegetation in the respective types as well as for failures to establish exotic and indigenous species adapted to types of higher effective temperatures. In the spruce-fir type only those species which can complete their development to maturity in minimum time, provided, of course, that their perpetuation is dependent wholly or primarily on seed, are conspicuously in evidence and of economic importance. This tendency toward early maturity is evident, for example, in the case of mountain brome grass, less days beirg required in all type stations for its flower production than for that of peas and wheat.

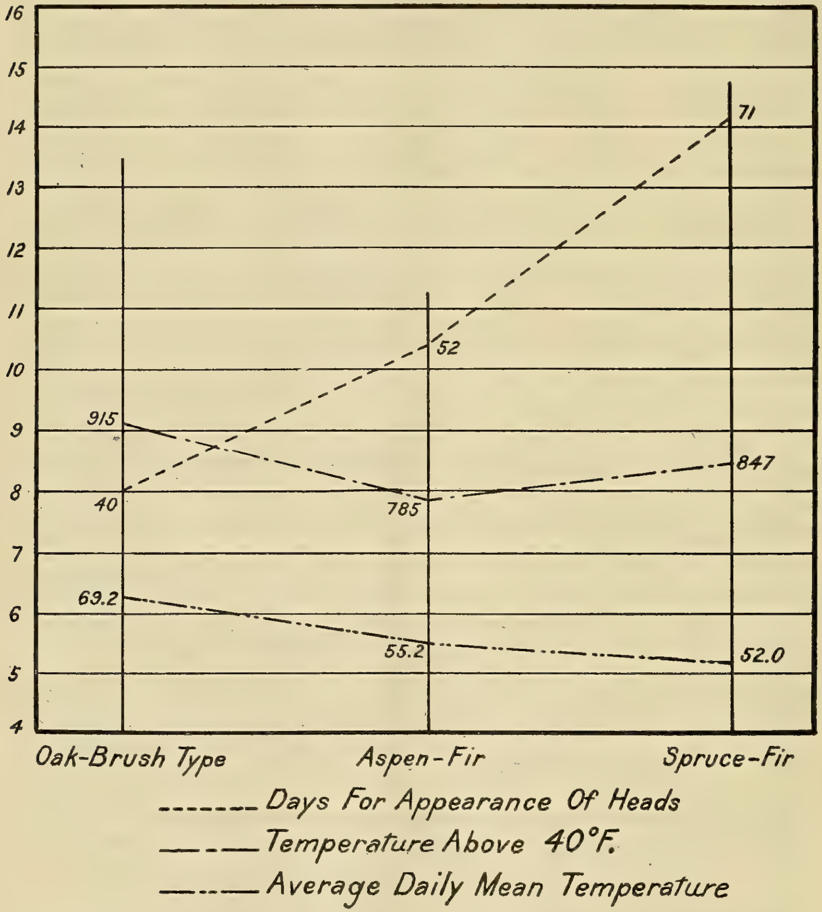

FIG. 28.—Relation of temperature to time of first appearance of heads of wheat.

EFFECT OF TEMPERATURE AS INDICATED BY WATER REQUIREMENT PER UNIT OF LEAF AREA.

The water requirements per unit of area of the chief food manufacturing agents of plants—the leaves—may be used as an index of the efficiency of the leaves as users of water. The leaf length is used instead of actual leaf area in the data given below, since, as has been previously shown, it is proportional to the actual area.

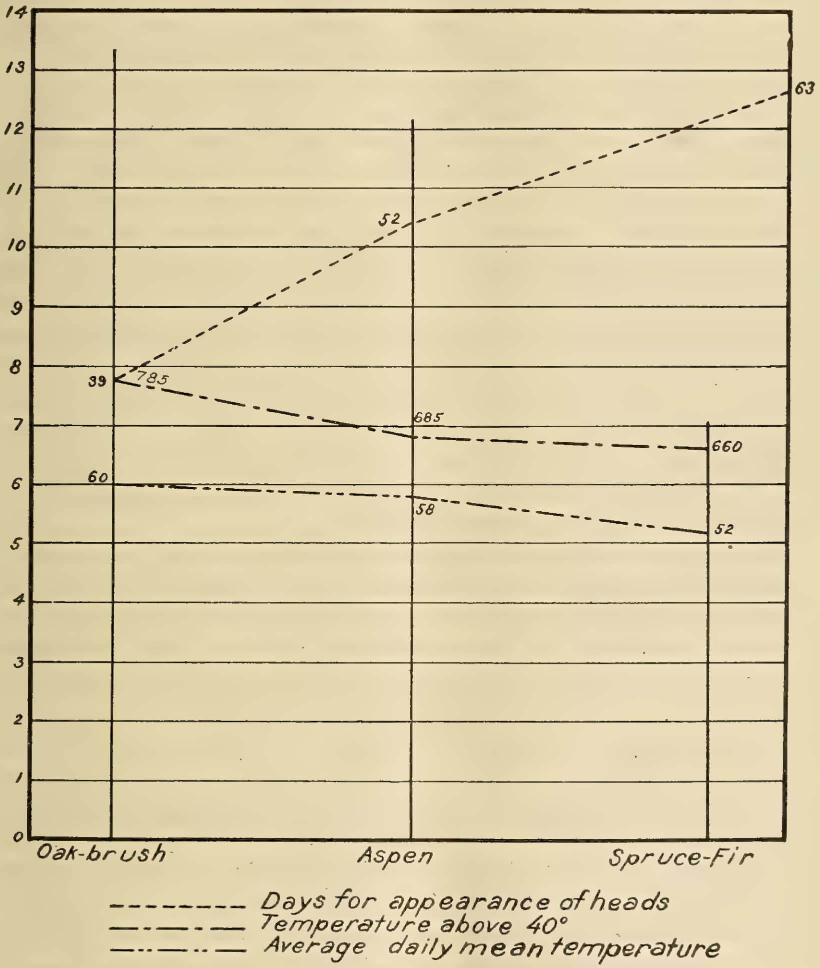

FIG. 29.—Relation of temperature to time of first appearance of heads of brome grass.

TABLE 15.—*Water requirements per millimeter of leaf length of wheat and brome grass in type stations.*

Type.	Temperature above 40° F.	Per cent difference in water requirements between wheat and brome grass.	Water requirements per millimeter leaf length.		Physiological temperature efficiency.
			Wheat.	Brome grass.	
	Degrees.		*Grams.*	*Grams.*	*Index.*
Oak-brush	2,002	312	1.000	0.321	2,706.2
Aspen-fir	1,404	195	.526	.273	1,560.5
Spruce-fir	991	127	.407	.319	730.5

Wheat uses nearly twice as much water per millimeter leaf length in the oak-brush type as in the aspen-fir type, and more than twice as much as in the spruce-fir type (fig. 30). In other words, water appears to be used most conservatively by a unit of wheat-leaf area in the type showing the lowest physiological temperature efficiency and temperature summation above 40° F., and most extravagantly in the type of highest temperature efficiency. Hence the curve representing the water requirement of wheat and the temperature summation curves fall from the type lowest in elevation to that of highest altitude in the same general way.

In the case of brome grass the water requirement of the leaves is found to be practically the same in all types in spite of the difference in the climatic conditions and in the stage of development of the plants. The reason for this dissimilarity between the two species is not entirely clear, but it may be related to the fact that mountain brome grass does not naturally inhabit the oak-brush type, though, indeed, the specimens observed appeared to develop normally.

In all instances a given leaf area of brome grass has a lower water requirement than wheat. Notwithstanding this fact, however, the water requirement per unit of dry matter for the plant as a whole, as previously shown, is greater for brome grass than for wheat. This is largely accounted for by the fact that the aerial part of mountain brome grass consists essentially of leaf blades, while a large proportion of the aerial dry matter of wheat is made up of stems and heads, the transpiration from which is low as compared with leaf surface. This relation between the water requirements of leaves of the two species is further shown by the curve representing the water requirement per millimeter of leaf length of wheat expressed as a percentage of the water requirement per millimeter of leaf length of brome grass. These percentages, which are 312 in the oak-brush type, 195 in the central station, and 127 in the spruce-fir type, indicate that wheat becomes relatively more efficient in the use of water as compared with brome grass as the temperature falls.

Furthermore, the curve representing these percentages bears an intimate agreement with both of the temperature summation curves. This increased conservatism in the use of water in wheat leaves may,

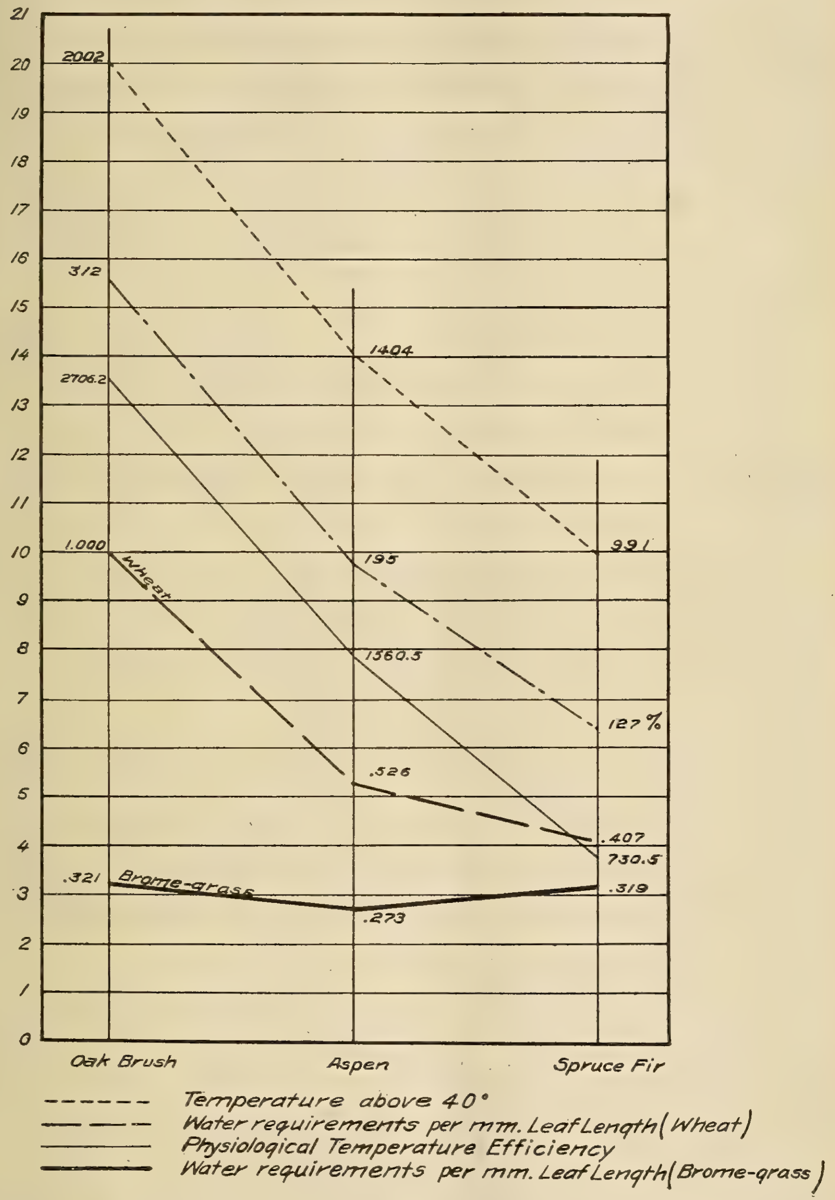

FIG. 30.—Water requirements per unit (1 mm.) of leaf length of brome grass and wheat.

in a way, account for the high yielding qualities of wheat, other conditions remaining the same, in regions where the summers are relatively cool.

EFFECT OF EVAPORATION AND TEMPERATURE ON THE PRODUCTION OF DRY MATTER PER UNIT OF LEAF AREA.

Quite as significant as the difference in water requirements per unit of leaf area in the respective types is the effect of climatic conditions on the efficiency of the leaves as manufacturing agents. This has been calculated for wheat and brome grass, the same specimens being employed as were used in deriving the water requirement data. The summations are given in Table 16 and in figure 31.

TABLE 16.—*Dry matter produced per millimeter of leaf length of wheat and brome grass in the type stations.*

Type.	Dry weight.		Per cent difference in dry weight of wheat and brome grass.	Evaporation summation.	Physiological temperture efficiency.
	Wheat.	Brome grass.			
	Grams.	*Grams.*		cc.	
Oak-brush	0.00161	0.00040	403	4,550.0	2,706.2
Aspen-fir	.00182	.00054	338	2,780.3	1,560.5
Spruce-fir	.00136	.00042	324	4,251.3	730.5

Both curves in figure 31 representing the dry matter per unit of leaf area show a maximum for the central type, the greatest concavity upward occurring in the curve for wheat. This species also shows a slightly greater production in the oak-brush type than in the spruce-fir type. In brome grass the reverse occurs, but in neither instance is the difference particularly marked.

It is significant that the curve representing the production of dry matter is opposite in slope to the curve showing the evaporating power of the air. The data indicate that evaporation decreases the rate at which the leaves manufacture food material, and the similarity in the production of dry matter in the case of both species in the three types may thus be accounted for by corresponding similarities in the evaporation conditions.

Another interesting parallelism is derived by dividing the dry matter per unit of leaf length produced by wheat by the quantity produced by brome grass. In this instance the curve is seen to fall from the lowest to the highest type in the same general direction as the physiological temperature efficiency curve. This apparent correlation between temperature and the efficiency of the leaves as manufacturing agents is of value, of course, only if it may be assumed that the physiological index affords a reliable expression of the relation between the temperature and the plants here dealt with.

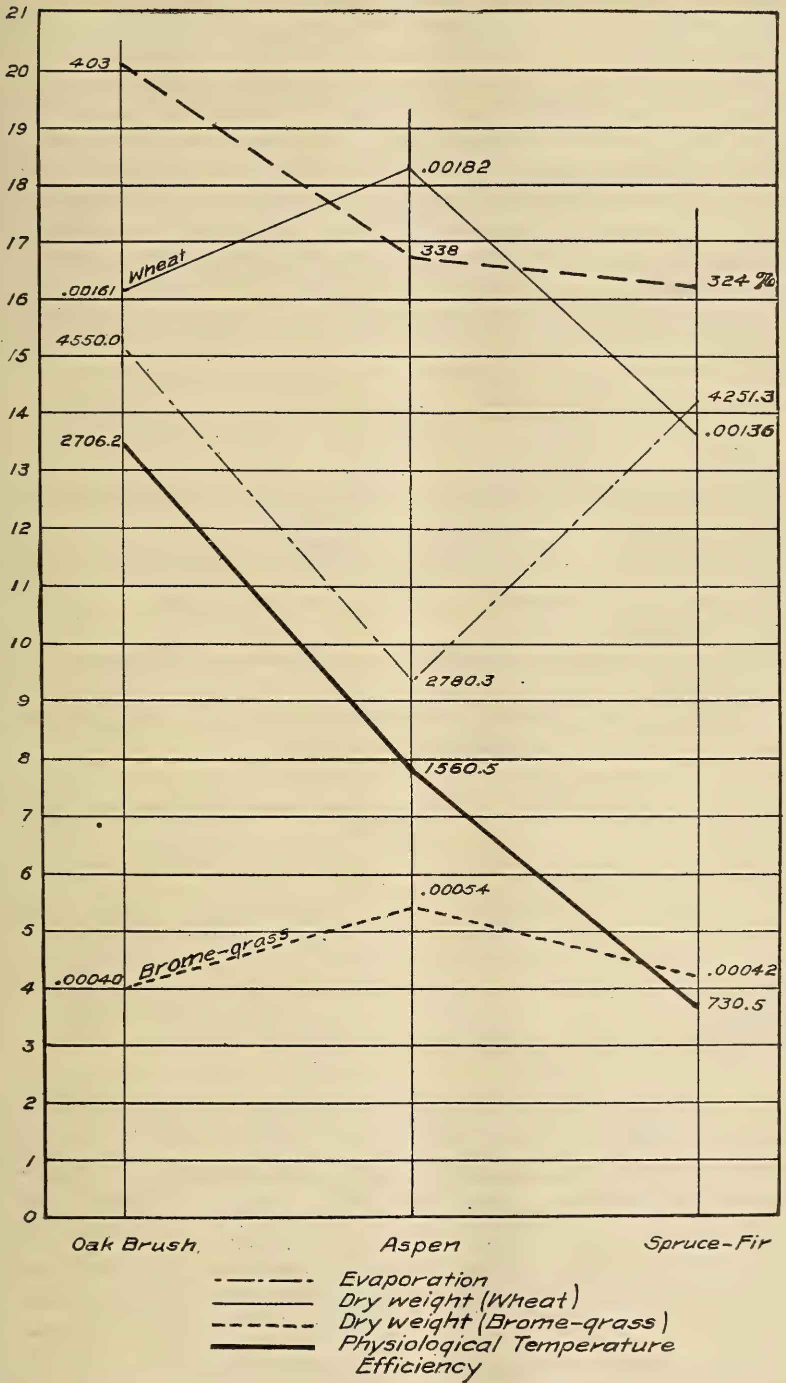

FIG. 31.—Dry matter produced by one millimeter of leaf length by brome grass and wheat (heads included).

EFFECT OF EVAPORATION AND TEMPERATURE ON THE GROWTH OF THE PLANT AS A WHOLE.

It has been shown that the efficiency of the leaves, both as users of water and as producers of material, is much influenced by climatic conditions. The true significance of this fact, however, can be fully understood only when the development of the plant as a whole, including stem height, total seasonal and periodic leaf expansion, and similar activities, is correlated with the controlling climatic factors.

Temperature and evaporation are, as the preceding discussion has shown, undoubtedly the limiting factors in the locality in which this investigation was conducted, and hence it is the chief aim to show physiological activities in relation to these factors.

EFFECT OF EVAPORATION AND TEMPERATURE ON THE GROWTH OF WHEAT.

Since more measurements were taken in the case of wheat than of the other species, wheat is here selected to show correlations between its development and temperature and evaporation. In this connection it should be stated that the correlations obtained between climatic factors and growth of wheat hold generally for the other species employed.

Four sets of measurements of wheat and the daily temperature and evaporation obtained for the period of growth concerned were recorded in each type station simultaneously. The data are summarized in Table 17 and platted in figure 32.

TABLE 17.—*Growth of wheat as related to evaporation and temperature in type stations.*

Type.	Evaporation.	Temperature above 40° F.	Average stem length.	Dry weight per plant.	Leaf length.	Water used per plant.
	cc.		*Mm.*	*Grams.*	*Mm.*	*Grams.*
Oak-brush	39,563	1,789	1,100	6.33	3,938	3,949
Aspen-fir	27,803	1,404	1,018	15.61	8,560	4,499
Spruce-fir	42,513	991	830	7.19	5,221	2,147

In figure 32 the direction of slope of the graphs representing total leaf length and average dry weight per plant is similar, a pronounced convexity upward occurring in the aspen-fir association. These measurements, then, are in inverse proportion to the evaporation. On the other hand, no apparent correlation exists between the curves representing the average stem length and evaporation. Since the curve of evaporation bears no distinct correlation to the temperature summation curve, it would appear that the height growth, or elongation of the plant, is determined more by the temperature than by the evaporation, the factor which apparently determines elongation and ex-

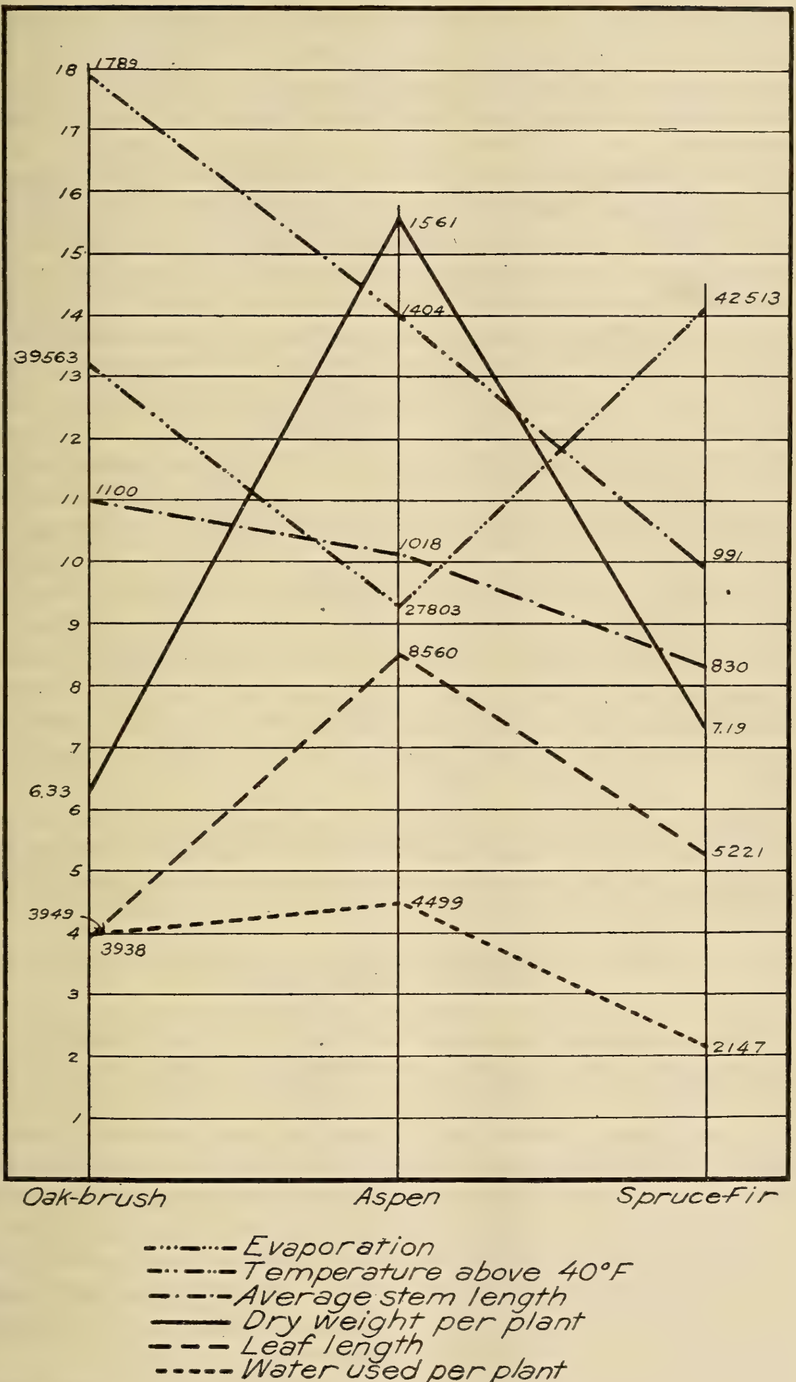

FIG. 32.—Comparison between climatic factors and the growth of wheat.

pansion of the leaf. The curve representing the water used per plant, on the other hand, is more or less intermediate in slope between the temperature and evaporation summation curves, and it is indicated that the water used per plant is determined both by temperature and evaporation.

The above figures are based on average measurements of 20 specimens in each type, but the data may not be adequate to justify the statement that leaf elongation and expansion of plants in general are locally, and under similar conditions, controlled more by evaporation than by temperature. Where the evaporation is especially high owing chiefly to factors other than high-wind movement, however, as in the oak-brush type, the data appear to warrant the conclusion that evaporation is the limiting factor in leaf expansion and consequently in the production of dry matter and other physiological activities of economic importance. This conclusion is further substantiated by the data presented in figures 30 and 31, showing on the one hand relatively high water requirement and on the other a correspondingly low production of dry matter in a unit of leaf area in the oak-brush type. The correlation between high evaporation and low production of dry matter may be explained either by the lack of proper turgor in the leaf cells during the long diurnal periods of high transpiration, or by the fact that egression of water molecules from the stomata and cells adjacent thereto is so great as to prevent free ingression of carbon dioxide essential to photosynthesis.

From the lower border of the aspen-fir type (about 8,000 feet elevation) throughout this association and in the less exposed sites of the spruce-fir type temperature and evaporation may exert equal effect on the plant.

EFFECT OF EVAPORATION AND TEMPERATURE ON SEASONAL MARCH OF GROWTH RATES OF WHEAT AND BROME GRASS.

While a measure of the relation of climate to the development of vegetation may be integrated by summarizing the climatic data and recording the dry matter produced by comparable plants during the entire growing season, the relation may best be known through concrete comparisons made at more or less regular intervals throughout the season. This is especially true of the more elevated regions, where weather within a season is subject to wide variation. Even if the relations between plant growth and weather were known, however, the factors affecting growth vary in a more or less unpredictable manner, so that the yield of a given crop could not be correctly judged much in advance of actual harvest.

If the assumption that leaf-expansion rate is retarded by evaporation is correct, the graph of evaporation platted period by period for the season at any given station should show an opposite slope to the corresponding graph of leaf-expansion rate. In order to determine whether such a relation exists, the rate of leaf expansion was calculated for the periods for which plant measurements were made, as was also the evaporation rate.

The values of seasonal march of leaf-growth rate given in Table 18, and graphically shown in figures 33, 34, and 35, represent average daily increase in length per leaf for the various culture periods. This quantity was obtained for each period by dividing the total leaf length produced up to the time of measurement by the total number of leaves, thus giving the average length per leaf. The increase in the average length per leaf of the plants from period to period was then determined by subtracting from each of the average leaf-length values the corresponding value of the preceding period. Since the periods for which measurements were taken varied somewhat in time, these increases, in order to make them comparable, were reduced to daily rates by dividing each increase in average leaf length by the number of days in which the increase took place. The physiological

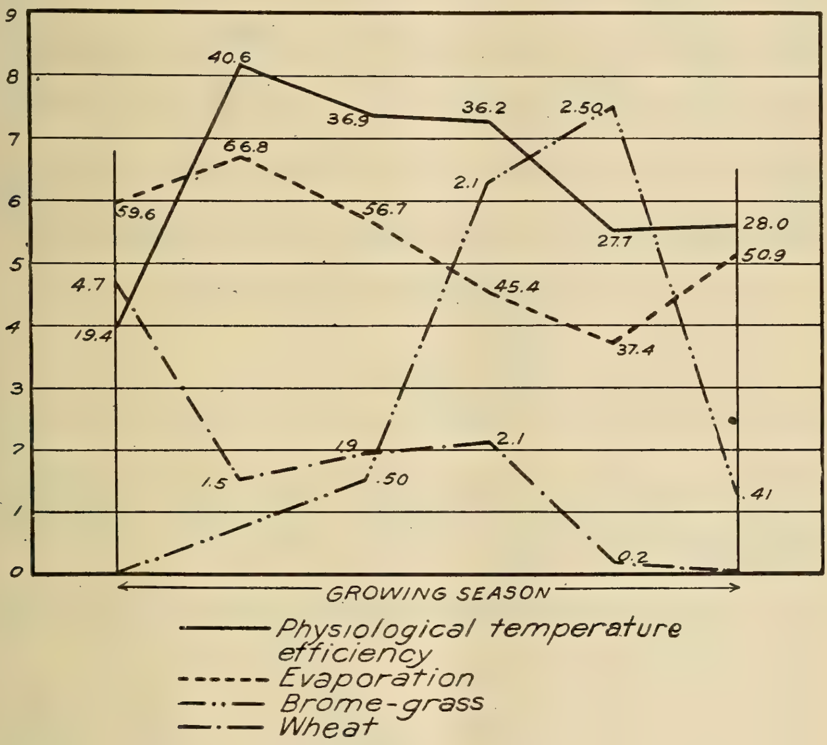

FIG. 33.—Periodic relation between leaf expansion, evaporation, and temperature, oak-brush type.

temperature index and the evaporation rate were also expressed as average daily rates in order to make these climatic factors comparable to the plant measurements. The data were recorded practically simultaneously at about 10-day intervals in each association. The first measurements here recorded are for June 22—10 days after establishing the potometers.

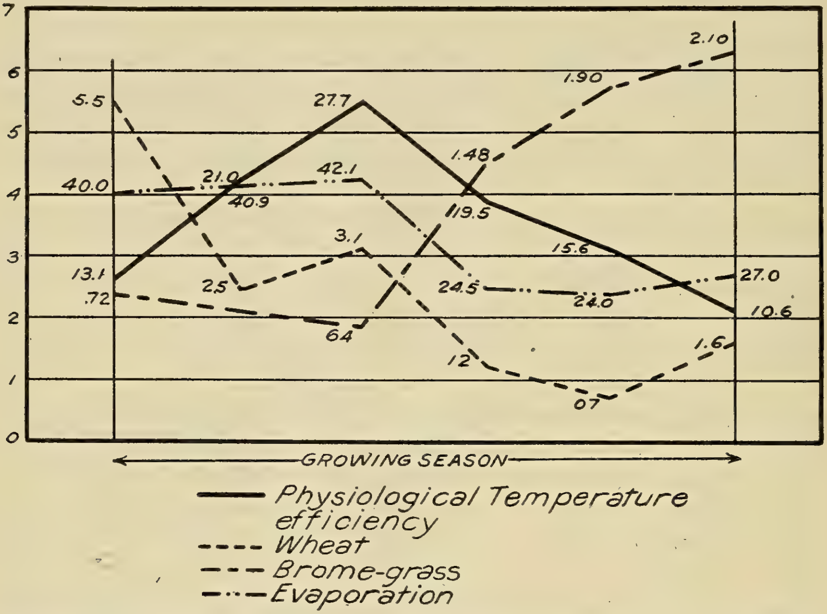

FIG. 34.—Relation between increments of leaf expansion, evaporation rate, and temperature, aspen-fir type.

TABLE 18.—*Effect of evaporation and temperature on leaf expansion of wheat and brome grass in type stations at about 10-day intervals, beginning June 22, through growing season.*

Association.	Brome grass.	Wheat.	Physiological temperature efficiency.	Evaporation summation.
	Mm.	*Mm.*		*cc.*
Oak-brush	0	4.7	19.4	59.6
	....	1.5	40.6	66.8
	.50	1.9	36.9	56.7
	2.10	2.1	36.2	45.4
	2.50	.2	27.7	37.4
	.41	.0	28.0	50.9
Aspen-fir	.72	5.5	13.1	40.0
	....	2.5	21.0	21.0
	.64	3.1	27.7	42.1
	1.48	1.2	19.5	24.5
	1.90	.7	15.6	24.0
	2.10	1.6	10.6	27.0
Spruce-fir	2.00	1.90	5.8	50.0
	1.10	.30	9.8	83.1
	1.90	2.40	12.5	59.6
	2.30	2.80	10.8	38.8
	6.50	2.10	7.4	30.0
	6.10	.85	5.7	49.0

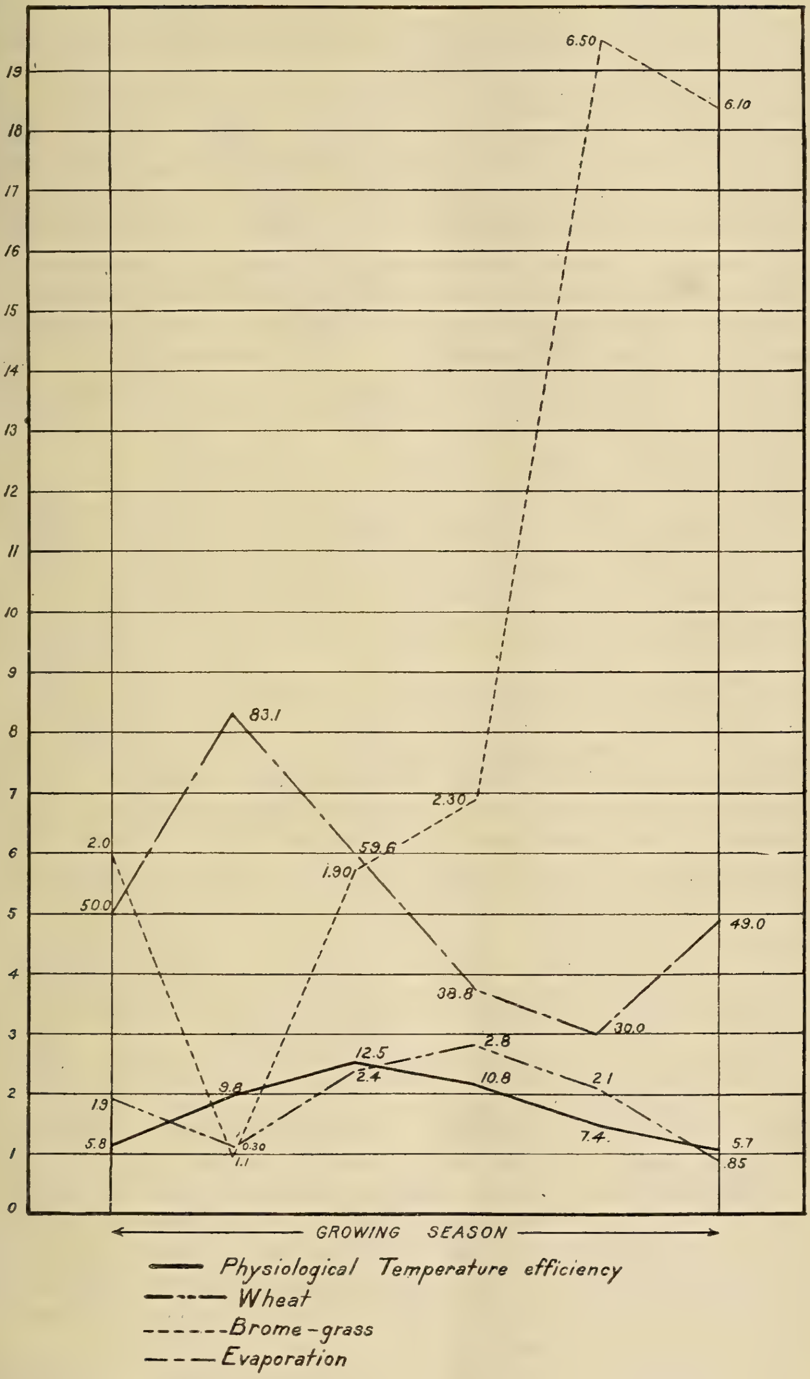

FIG. 35.—Relation between increments of leaf expansion rate and temperature, spruce-fir type.

The curves (figs. 33, 34, and 35) representing leaf expansion, in some instances at least, follow the temperature curves, but in general slope in opposite direction to the curves portraying the evaporation rate. Exception to the latter occurs in the case of wheat in the aspen-fir type; but data already presented have shown that evaporation is not a limiting factor for this plant in this type. Also it will be seen that growth toward the end of the season does not in all cases bear an inverse relation to evaporation. As an explanation of this fact it should be stated that the leaf growth is rapidly declining at that time, because of the approach of maturity of the plants. On the other hand, there appears to be no consistent correlation between growth increments and temperatures. The agreements that do occur also show a direct correlation between growth and evaporation, and hence it may be concluded that the temperature and growth relations recorded are more or less incidental.

Considering the graphs more in detail, in the case of figure 33 the leaf increment curves of both species in practically all instances have concavities opposite in direction to those of the curve representing the evaporation. It should be stated that no growth data were obtained for brome grass in the second period of measurements, and therefore the slope of the line at that point is not in agreement with the growth curve for wheat, nor is it in opposition to the slope of the evaporation curve. In the case of wheat, the leaf expansion curve and the evaporation values platted for the first three periods show inverse relation. Between the fourth and fifth periods there is a slight disagreement in these values, but between the fifth and sixth periods the leaf measurement and evaporation curves again show opposite trend. The leaf increment curve for brome grass, on the other hand, is in inverse proportion to the evaporation in all instances.

As would be expected, where evaporation is unusually high, as in the oak-brush type, temperature in general is high, and these factors usually run more or less parallel. This being the case, it is hardly to be expected that the growth increments would follow the physiological temperature indices. As is well known, the growth rate increases with increase in temperature up to the optimum requirement of a given species. In the oak-brush type there is reason to believe that the temperature not uncommonly exceeds the optimum requirements of the species observed. The lack of correlation between growth rate and temperature in the oak-brush type, then, would seem to strengthen the evidence that the evaporation in that association is the determining factor in the rate of elongation as well as ultimate expansion of the leaf.

In figure 34, in which similar data are given for the aspen-fir type, wheat, except in one instance follows the evaporation curve, hence to some extent that of the temperature; while in the case of brome grass the leaf expansion curve slopes opposite to the evaporation curve. In the central type, the evaporation being less than in the lowest and the highest types (fig. 8), in no instance has proved a limiting factor for the type in question so far as concerns the physiological activities of wheat. In the case of brome grass, however, the contrary is true. The reason for the difference in the response of these species is not obvious.

In the spruce-fir type figure 35 shows that the leaf increment values in the case of brome grass are in inverse proportion in every instance to those of evaporation.[1] Hence, between the first and third periods, when the highest rate of evaporation occurs, is recorded the lowest rate of leaf expansion for the entire period; and between the fourth and sixth periods, which marks the lowest rate of evaporation, by far the highest growth rate is recorded. The rates of leaf expansion in wheat likewise show inverse relation to evaporation, though less pronounced than the leaf-expansion rates of brome grass, with the exception of the next to the last period. This disagreement, however, is explained by the fact that the wheat specimens were approaching maturity and the growth rate was, therefore, beginning to decline.

As in previous instances, the curve showing the growth rate of wheat in the spruce-fir type seems to follow, in a general way, the daily temperature curve, but this is evidently more or less incidental. In order to determine these relations more definitely, averages of daily leaf increment of wheat and of temperature and evaporation were computed for the season as a whole, the results of which are platted in figure 36. From these curves it is evident that leaf increment of wheat is in inverse proportion to evaporation, no obvious relation to temperature being shown. This relation is also found to hold in the case of brome grass.

To sum up the facts regarding the relation of leaf expansion to evaporation and temperature: The daily rate of growth of the species studied, as well as the total leaf surface produced, varies inversely as the evaporation, except in the case of the daily rate for wheat at the middle station. Evaporation in the aspen-fir type is lower than in the types immediately above and below. As a limiting factor the evaporation may be declared transitional in a sense— that is, it may determine growth rate periodically or seasonally in one species, but not distinctly so in another. Since temperature and evaporation are admittedly more or less interrelated, it is difficult to separate them; consequently, their individual effect on the activities of the plant can not be definitely declared in all instances.

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[1] As previously shown, the high evaporation in the spruce-fir type is chiefly accounted for by high wind movement.

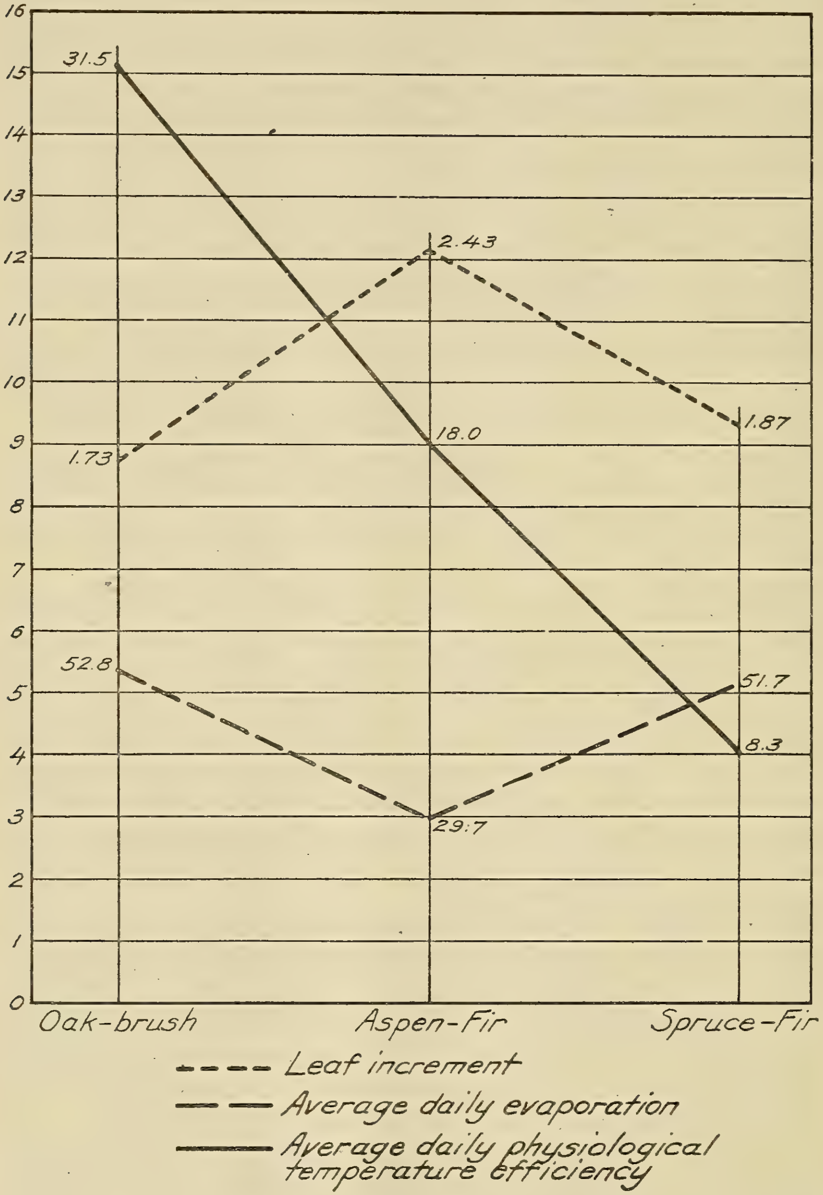

FIG. 36.—Average daily increment in leaf expansion of wheat throughout season compared with evaporation and temperature in type stations.

EFFECT OF TEMPERATURE AND EVAPORATION ON WATER REQUIREMENTS OF PLANTS.

Since the rate of growth and production of dry matter by plants appear to be controlled chiefly by evaporation and temperature, so far as physical factors in the locality here dealt with are concerned, it appeared pertinent to determine whether or not the water requirement is also correlated with the factors mentioned. The value of data showing the relative water requirement of different plant species has been demonstrated by numerous investigators. The climatic factors that chiefly affect the rate of dissipation of water through transpiration, on the other hand, have until very recently received relatively little attention, although such researches would appear to be of profound economic importance. If it were known, for instance, that in a region of limited rainfall the evaporation was largely responsible for the high transpirational demand and consequently the high water requirement of a given plant, habitats might be selected where vegetation, natural barriers, or other features would afford protection against excessive evaporation. Likewise, if temperature were the factor determining the water requirement, cool north and east slopes, or possibly partially shaded sites might be selected at least at lower elevations and failure of crop production thus avoided.

In order to determine the relation of water requirement of these plants to evaporation and temperature in the type stations, the water used per unit of dry matter by wheat, peas, and brome grass, through practically the entire growing season, was divided by the evaporation for the corresponding period. Tabular and graphic presentation of the results follows.

TABLE 19.—*Effect of temperature and evaporation on water requirements of plants grown in type stations.*

Type.	Species.	Physiological temperature efficiency.	Water requirement per unit dry matter.	Evaporation for period of growth.	$\frac{W.R.}{E.}$
			Grams.	*c c.*	
Oak-brush	Wheat	2,473.7	626	3,956.3	0.158
	Peas		779		.197
	Brome grass		803		.203
Aspen-fir	Wheat	1,560.3	288	2,780.3	.104
	Peas		368		.132
	Brome grass		516		.186
Spruce-fir	Wheat	730.5	300	4,251.3	.071
	Peas		345		.081
	Brome grass		756		.178

As has been shown in previous graphs, the physiological temperature efficiency is highest in the oak-brush type, the curve dropping in practically a straight line to the central and highest types. The quotients of the values derived by dividing the water requirement per unit weight of dry matter for the respective types by the evaporation for each period $\left(\frac{W.R.}{E.}\right)$ when platted (fig. 37) are likewise found to be highest in the oak-brush type, intermediate in the aspen-fir type, and lowest in the spruce-fir type, the curves in the case of each species following in a general way the physiological temperature indices.

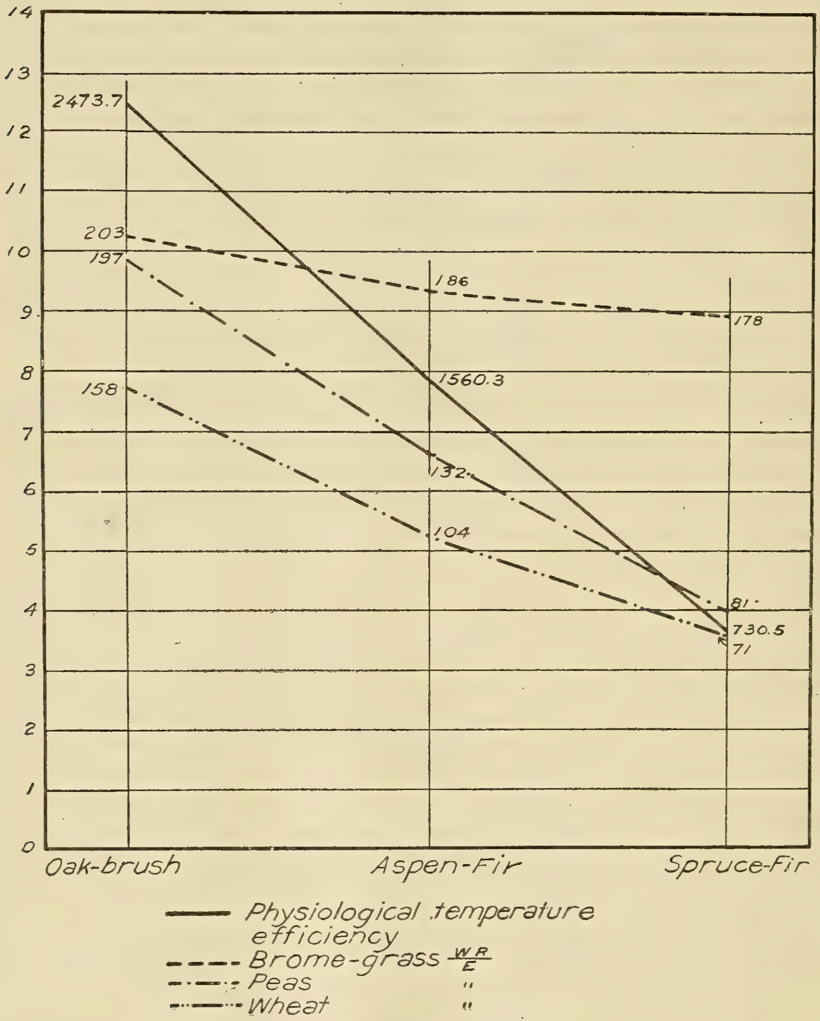

FIG. 37.—Relation of the quotient of water requirement and evaporation $\left(\frac{W.R.}{E.}\right)$ to temperature.

On the basis of the agreements shown, it may be concluded that the water requirement of these plants is determined largely by evaporation and temperature. Hence it is evident that in localities of limited rainfall, high evaporation, and high temperature values, agricultural pursuits, even where the most drought-resistant species may be economically employed, should be confined to soils of high water-holding capacity and subject to minimum run-off, so that the soil may return to the plant a high percentage of the rainfall.

SUMMARY.

The data reported, pertaining as they do (A) to the climatic characteristics of three distinct vegetative associations, (B) to comparative instrumentation and methods of summarizing and expressing climatic factors, and (C) to correlations between environmental factors and plant growth and other physiological activities, may best be summarized under three heads.

A. CLIMATIC CHARACTERISTICS OF THE PLANT ASSOCIATIONS.

1. The mean annual temperature increases gradually from the highest to the lowest type, and this results in the longest growing season in the lowest type and a gradual decrease in the period of growth with increase in elevation. Thus from the time of the beginning of growth to the occurrence of killing frosts there are about 120 days in the oak-brush type, 105 in the aspen-fir type, and 70 in the spruce-fir type.

2. The normal annual precipitation is greatest in the aspen-fir association but is only slightly heavier in this association than in the spruce-fir. Less than half as much precipitation is recorded in the sagebrush-rabbit-brush as in the aspen-fir association; and in the oak-brush type it is only slightly greater than in the sagebrush-rabbit-brush type. The precipitation is rather uniformly distributed throughout the year.

3. Of the three associations critically studied, the evaporation during the main growing season is greatest in the oak-brush type; but owing to high wind velocity in the spruce-fir type the evaporation is nearly as great as in the oak-brush type. In the aspen-fir type the evaporation factor is notably less than in the types immediately above and below. This is accounted for largely by the lack of high wind velocity, which is due to the luxuriant vegetation and to topographic features.

4. The wind movement is greater by about 100 per cent in the spruce-fir association than in the types immediately below. Not uncommonly the velocity of the wind exceeds 40 miles per hour for several hours in succession. In the lower types the velocity averages slightly less than half that recorded in the spruce-fir type.

5. Sunshine duration and intensity are practically the same in all types studied.

6. There is considerable difference in barometric pressure in the respective types, but the daily seasonal fluctuations within a station are slight.

B. COMPARATIVE INSTRUMENTATION AND METHODS OF SUMMARIZING EXPRESSIVE CLIMATIC FACTORS.

1. Temperature summations on a physiological basis according to the Lehenbauer plan have shown much promise in correlating air temperature with physiological plant activities. The summation of the effective temperature, namely, the temperature above 40° F., as proposed by Merriam, also appears to have much promise. This method in general compares favorably with temperature summations made on the physiological (Lehenbauer) basis.

2. Summations of average daily mean and seasonal mean temperatures appear to have little value in showing correlations between the factor in question and physiological activities in plants.

3. The evaporation for short periods, such as a part of a day or a fractional part of a week, for example, when compared with relative humidity, temperature, and wind velocity, can be obtained more accurately by means of the porous cup atmometer than by the free water surface evaporimeter of the Weather Bureau pattern. For periods of a week or longer either instrument will serve.

4. In recording sunshine as related to plant activities, both duration and intensity should be considered. Such records can be obtained approximately by noting the difference in evaporation between similarly exposed black and white porous cup atmometers. These instruments appear to have some advantages over the Marvin sunshine recorder, which furnishes a record only of sunshine duration.

C. CORRELATIONS BETWEEN ENVIRONMENTAL FACTORS AND PLANT GROWTH.

1. Lack of uniformity in the fertility and, of course, in the texture of the soil in which the plants are grown may cause considerable variation in their water requirements and in the total dry matter produced. Soil collected within a restricted habitat often varies considerably in productivity, and unless thoroughly mixed may become an important source of error in experimentation.

2. The total effective heat units and length of growing season in the three types studied are such that only in the lowest association do crops like wheat and peas reach full maturity. Hence, farmers should not attempt locally to grow the ordinary agricultural crops, such as cereals, above an elevation of about 8,000 feet. The elevation at which there are normally sufficient heat units to develop and mature cereal crops in general varies, of course, with the latitude and longitude.

3. The rate of maturity of the plants decreases directly as the effective heat units decrease, as is the case in passing from the lowest to the highest type. This decrease in the rate of maturity of the plant in the type stations may be shown, up to a certain point, at

least, by the difference between the water requirements of the aerial parts of the plants, including the fruit or seeds (such as the heads of wheat), and of the aerial portion without the seeds, the specimens with the best developed seeds, of course, having the highest water requirements.

4. The water requirement for the production of a unit weight of dry matter is greatest in the oak-brush type, lowest in the aspen-fir type, and intermediate in the spruce-fir type. These relations coincide with the relative intensities of the evaporation.

5. In the case of all species employed, the total, and, indeed, the average leaf length and total dry weight produced are notably greatest in the aspen-fir association, these activities being rather similar in the spruce-fir and oak-brush types. The decreased production in leaf length and the production of dry matter in the respective types are in direct proportion to the evaporation.

6. The elongation of the stem is greatest in the oak-brush type, intermediate in the central type, and least in the aspen-fir type. Thus stem elongation appears to be determined largely by temperature and seems to be little influenced by the intensity of the evaporation.

7. The efficiency of the leaves per unit area as manufacturing agents—that is, in the production of dry matter, appears to vary inversely with the evaporation, though, indeed, temperature appears to be one of the important factors. The largest amount of dry matter per unit of leaf area is produced in the aspen-fir type and the least in the oak-brush type, while in the spruce-fir type, where the evaporation is only slightly less intensive than in the oak-brush type, the dry matter produced is only slightly greater than in the oak-brush type.

CONCLUSIONS.

From the study here reported, it may be concluded that in this locality Kubanka wheat and Canadian field peas, and doubtless other agricultural crops, can not be grown profitably at elevations exceeding about 8,000 feet because of the lack of sufficient heat. As has been shown by the crop production of the region, enough heat units were produced in the seasons studied up to an altitude of about 8,000 feet, which includes most of the oak-brush type, to mature wheat, peas, and certain other crops. The amount of precipitation received at an elevation of 8,000 feet and lower, however, was below the requirements of crop production, indicating that the lands must either be irrigated or the moisture conserved by thorough summer fallowing. The native forage crop produced in the oak-brush type, on the other hand, is fairly luxuriant, and if properly utilized will continue to be of high value in the pasturing of live stock. On the more favorable sites from the oak-brush up to and including the spruce-fir association, lands which have been overgrazed and are not fully stocked with vegetation may be increased in forage production by the seeding of suitable plants, preferably native species.[1]

Since evaporation is apparently the chief factor limiting growth and development of plants in the oak-brush and spruce-fir types, the extension of agriculture and forestry should be limited to lands protected from excessive evaporation. This may be done by selecting sites that are more or less protected by native vegetation and natural obstacles. Failures in experimental plantings, in most instances, have occurred on wind-swept lands where the soil moisture becomes deficient early in the season. In the selection of species, either of herbaceous or of woody plants, only the most drought resistant sorts should be used. Failures in the case of the planting of suitable timber species in the central (aspen-fir) type will probably seldom be caused by adverse climatic conditions. Failures in this type may generally be traced to the employment of unsuitable stock, or to bad workmanship, wrong season of planting, or other preventable causes.

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[1] Sampson, Arthur W. Natural revegetation of range lands based upon growth requirements and life history of the vegetation. Journ. of Agr. Research, Vol. III, No. 2, 1914.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 676

Contribution from the Forest Service
HENRY S. GRAVES, Forester

FOREST PRODUCTS LABORATORY, Madison, Wisconsin
In Cooperation with the University of Wisconsin

Washington, D. C. PROFESSIONAL PAPER July 16, 1919

THE RELATION OF THE SHRINKAGE AND STRENGTH PROPERTIES OF WOOD TO ITS SPECIFIC GRAVITY

By

J. A. NEWLIN, in Charge, Section of Timber Mechanics, and T. R. C. WILSON, Engineer in Forest Products

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Determination of Specific Gravity 6
Moisture Content of Test Specimens 6
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UNITED STATES DEPARTMENT OF AGRICULTURE

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Contribution from the Bureau of Soils
MILTON WHITNEY, Chief

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SOILS OF SOUTHERN NEW JERSEY AND THEIR USES

By

J. A. BONSTEEL, Scientist in the Soil Survey

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 680
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MISCELLANEOUS CONIFERS OF THE ROCKY MOUNTAIN REGION

By

GEORGE B. SUDWORTH, Dendrologist

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 681

Also Bulletin 26 of The Engineering Experiment Station
The Pennsylvania State College

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief
and the Engineering Experiment Station of The Pennsylvania State College
R. L. SACKETT, Dean

Washington, D. C. ▼ May 18, 1918

GRAIN-DUST EXPLOSIONS

INVESTIGATION IN THE EXPERIMENTAL ATTRITION MILL AT THE PENNSYLVANIA STATE COLLEGE

By

B. W. DEDRICK, Instructor in Milling Engineering, and R. B. FEHR, Assistant Professor of Mechanical Engineering, The Pennsylvania State College, in collaboration with DAVID J. PRICE, Engineer in Charge, Grain-Dust Explosion Investigations, Bureau of Chemistry, Department of Agriculture

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 691

Contribution from the Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C. ▼ July 10, 1918

TYPICAL SPECIFICATIONS FOR BITUMINOUS ROAD MATERIALS

By

PRÉVOST HUBBARD, Chemical Engineer, and
CHARLES S. REEVE, Chemist

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 693

Joint Contribution from the Office of Farm Management
W. J. SPILLMAN, Chief
and
Bureau of Plant Industry
W. A. TAYLOR, Chief

Washington, D. C. ▼ July 16, 1918

FARM PRACTICE IN GROWING SUGAR BEETS FOR THREE DISTRICTS IN UTAH AND IDAHO, 1914–15

(A detailed study of field operations and current cost factors involved in the production of this crop in 1914–15 on 173 farms in the Provo and Garland districts, Utah, and the Idaho Falls district, Idaho)

By

L. A. MOORHOUSE, Agriculturist, and T. H. SUMMERS and R. S. WASHBURN, Scientific Assistants, Office of Farm Management; and JAMES W. JONES, Agriculturist, Office of Sugar-Plant Investigations, Bureau of Plant Industry

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Office of the Secretary
Contribution from Office of Farm Management
W. J. SPILLMAN, Chief

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A STUDY OF FARM MANAGEMENT PROBLEMS IN LENAWEE COUNTY, MICHIGAN

By

H. M. DIXON, Assistant Agriculturist and
J. A. DRAKE, Agriculturist

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LEON M. ESTABROOK, Chief

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GEOGRAPHICAL PHASES OF FARM PRICES: CORN

By

L. B. ZAPOLEON, Formerly of the Division of Crop Records

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CITRUS-FRUIT IMPROVEMENT: A STUDY OF BUD VARIATION IN THE MARSH GRAPEFRUIT

By

A. D. SHAMEL, Physiologist in Charge, L. B. SCOTT, Pomologist, and C. S. POMEROY, Assistant Pomologist, Fruit-Improvement Investigations, Office of Horticultural and Pomological Investigations

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WM. A. TAYLOR, Chief

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GRAIN-SORGHUM EXPERIMENTS IN THE PANHANDLE OF TEXAS

By

CARLETON R. BALL, Cerealist in Charge, and BENTON E. ROTHGEB, Scientific Assistant in Charge of Grain-Sorghum and Broom-Corn Investigations, Office of Cereal Investigations

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MILTON WHITNEY, Chief

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ANALYSIS OF EXPERIMENTAL WORK WITH GROUND RAW ROCK PHOSPHATE AS A FERTILIZER

By

W. H. WAGGAMAN and C. R. WAGNER, Scientists in Investigation of Fertilizer Resources, assisted by R. F. GARDINER, Scientist in Soil Laboratory Investigations

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HENRY S. GRAVES, Forester

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CLIMATE AND PLANT GROWTH IN CERTAIN VEGETATIVE ASSOCIATIONS

By

ARTHUR W. SAMPSON, Plant Ecologist
Forest Service

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